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NOVEMBER 10¢

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CONTENTS

ON THE COVER

Romance flies high, as AAF girl-friend pins on bombardier's wings at Roswell, N. M. Army Flying School graduation The photograph is an official U. S Army Air Forces direct-color Kodachrome

PHOTOGRAPH CREDITS

Where more than one photograph appears on a page credits are listed in order by rows from left to right, top to bottom The number of consecutive pictures from each source appears in parenthesis after each name Page 1, Direct color photograph in full color U S Army Air Forces. Page 4, Lockheed-Vega Aircraft Corp ; Page 13 Press Association, Page 16 Official U S Navy, Grumman Aircraft Corp. Pages 17, 18 Official U S Navy, Pages 43 44 45, 46, 47 48 49, 50 51 Lockheed Vega Aircraft Corp , Page 52 Glenn L Martin Co , Page 57 Army Air Forces Show, Page 58, Rudy Arnold

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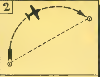
PRINTED IN THE UNITED STATES

AIRAGE REFRESHER by Eric Sloane

1

When a flyer calls for help on his Radiophone, he says:
- A. S.O.S.
- B. Christmas
- C. Mayday

2

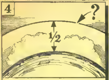


A Great Circle route is
- A. Any direct route
- B. A Northern air route
- C. A curved flight course

3

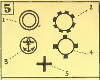
The magnetic North Pole is not on the geographical pole, in fact it is
- A. About 14 miles away
- B. About 140 miles away
- C. About 1400 miles away

4



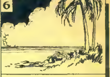
One half of all the atmosphere is below
- A. 280,000 feet alt.
- B. 37,500 feet alt.
- C. 18,000 feet alt.

5



These are map symbols for
- A. Airports
- B. Seaports
- C. Buoys

6



Hawaii is nearer to
- A. Japan
- B. Los Angeles
- C. The Aleutians, Alaska

7

Leaving Africa for America, the nearest land would be
- A. Florida
- B. Panama
- C. Maine

8

Pulling out from an inverted dive, the pilot would
- A. Black-out
- B. Red-out
- C. Turn white

9

Over 37,500 feet, many pilots are attacked with
- A. Anoxia
- B. Aeroneurosis
- C. Airsickness

Answers will be found on Page 58. AIR AGE REFRESHER by Eric Sloane will be published by the Devin-Adair Co.

THE AIRPLANE
WHIPS THE TANK

How Tankbusters and Stormoviks Licked the Panzer Divisions

By KEITH AYLING

Former R.A.F. pilot and author of "They Fly for Victory."

ONE of the strangest stories of this war is the constant battle between the airplane and the tank. The tank is losing steadily in spite of its increasing size and additional armor.

Today after years of war, the airplane is virtually the master of the descendants of the mechanical behemoths used by Hitler to crash his mighty armies through the defenses of Poland, France, Greece, North Africa and Russia.

Probably neither the Germans nor the British thought the airplane would be a menace to the tank except perhaps for the normal hazards of bombardment from the air. The answer to the tank was held to be the anti-tank rifle and 25-pounder field gun. The Germans allowed for these in advance, by fitting extra thick armor to their tanks, which carried guns that outranged and outfired the weapons used against them.

The desperately pushed French found a way of stopping the panzers by very unorthodox means.

They attacked the advancing tanks from the air, not with bombers, but with fighter planes. The planes were American made Curtiss Hawks, the guns 20 mm. Orlikon and Hispano cannon, firing armor piercing, explosive and incendiary shells. The fighter pilots of the French Armée De L'Air dived on the tanks, and aimed their shells obliquely at the unarmored tops of the tanks. According to one pilot who took part in the attack, and who later escaped to England, the tanks opened like sardine cans. They were blasted, burned, and stopped. "If we had had enough planes," said my informant, "we might have stopped them all, but we had not."

How many German armored vehicles and tanks were destroyed by the pilots of the Sioux squadron which started this means of attack, was never known. The squadron suffered heavy losses from anti-aircraft fire and German Messerschmitt fighters. One by one they were shot down or put out of action on the ground, till finally the gallant squadron had no planes to take to the air. The Panzer divisions crashed on, hardly disturbed by their losses, but the germ of an idea was born.

To the British Intelligence Service went reports of the success achieved by the French low flying attacks which were in pattern with the allied air offensive in the latter part of World War I, when Sopwith Salamander biplanes with machine guns firing at an angle to their line of flight, preyed on the retreating German transport columns.

The Germans learned a lesson from the attacks of the French fliers—that tanks were vulnerable to low flying attack. They immediately installed top armor plating in their new models. In the larger types they fitted heavy calibre anti-aircraft guns, which were quickly followed by larger shell firing guns. They supported their tank columns with armored flak vehicles aimed to screen the advance against attack from the air.

British experts gave a great deal of thought to the news from France. The failure of their own anti-tank rifles to stop the tanks was partly because the German armor was too tough, and partly because the gunners were unable to get within range of the monsters before being annihilated by the more powerful gunnery of the panzers. If a tank rifle or anti-tank gun could be fitted to an airplane, such a gun could be brought within range close enough to make it dangerous. The problem was to find the right type of gun, and the airplane to carry it.

The airplane needed to have certain definite qualities in addition to fire-power. These were speed, armor, and maneuverability at low altitude. It also needed sufficient power to carry small fragmentation bombs, and to be able to climb fast after delivering its punch. If such a plane could be designed, tank columns could be placed at a disadvantage as soon as they were located. The planes could attack them long before they came within range of the defending anti-tank guns.

The plane chosen for the experiment was the Hawker Hurricane, second-string hero of the Battle of Britain, one version of which was fitted with four 20 mm. cannon. Hurricane pilots had used these 20 mm. weapons with great effect against German coastal ships and armored trains running on the railways of Hitler's *Fortress Europe*. Against the improved German tank, however, even the heavy punch of four 20 mm cannon was considered insufficient. The tank-busting airplane had to pack a real heavyweight punch, that would make certain that an armored vehicle that was hit, would stay hit, either totally disabled or so badly afire that it would burn to a charred shell.

Could the Hurricane be made to carry an even heavier armament? Sidney Camm, the tall,

CONTINUED ON NEXT PAGE

quiet-voiced designer, who had already designed his Typhoon to carry more fire-power than any other plane that flies, believed it could. Experiments were carried out in secret. Captured German tanks were fitted with additional armor, and used as targets at an isolated airfield. For weeks the experiments were continued. Armament engineers, and plane designers held conferences that often continued through the night.

The ballistic experts insisted on certain specifications. The tank experts had set views. The fliers saw the problem from yet another standpoint. Many types of armor plating were tested, with guns of varying calibres and projectiles. In the early stages the armor-plating usually won, but, acting on the principle that perseverance finds the perfect answer to every situation, the experts continued doggedly.

When they felt they had mastered the existing type of German tank with a single 37 mm cannon similar to that fitted to our own Airacobras, they decided to go one better. They would use a machine fitted with guns of even heavier calibre, so arranged that a cone of fire with a hitting power of more foot pounds to the square inch per second than ever before fired from a fighter plane, would smash into the target.

The guns were to be the biggest ever carried on a plane. They were so large that it seemed impossible even to fit them to the plane. The job had to be done, insisted the military authorities—and it was. Finally to the North African front were dispatched a number of specially designed Hurricanes fitted with two of the biggest cannon ever fitted to aircraft. Each was of 40 mm. calibre and weighed 350 pounds. They fired armor piercing, explosive and incendiary shells weighing about 2½ pounds. The rate of fire was slow, the amount of ammunition limited, but the British felt they had got something.

One morning in the fall of 1942 the first tank-busting squadron went into action against a number of tanks advancing towards the British lines under clouds of sand. The tank-busting Hurricanes flew under a cover of Spitfires, and were supported by low flying Hurribombers, fighter planes of the same family, but fitted with small calibre guns and carrying fragmentation bombs.

A great experiment was about to take place. Which would come off best, the tanks, or the airplanes?

Imagine how tensely the "backroom boys," as the R.A.F call their staff, waited for the results of that action.

The Hurricane 20's, as the machines were typed, swooped low over the tanks, while their escorts fought off the ME 109's.

The pilots of the new machines had been carefully trained. Theirs was to be no hit and miss job. They had to hit their targets good and hard in the right place. On their skill depended an important round in the battle between the tank and the airplane. If they failed, the men in England who had labored for months, might have worked in vain, and the destruction of the tank might have to be left to anti-tank guns, the U. S. bazookas and low flying bombers.

The Hurricanes flew through a hail of fire sent up by the Afrika Korps gunners on the roofs of the German tanks. Lower, lower and nearer they came, roaring steadily down, each man choosing his target. The German gunners may have grinned a trifle as the first fire came from the planes—from a couple of rifle calibre machine guns. That fire was tracer bullets only, which bounced off the tank's armor like pellets from a kid's pea shooter. But immediately he saw his bullets hitting, the *Hurribuster* pilot pressed another trigger button and the biggest guns ever fired from an airplane got to work. Bang! Bang! Bang! The Hurricanes shuddered at the thwacking recoil of these mighty guns, fitted under the wings because they were too big to go inside. The tanks met unexpected destruction on the run. One by one they stopped as the shells crashed into their armour, shattered their treads, or swiped off their turrets. How many were destroyed in that encounter is a military secret known only to the Allied Air Forces, and to the losers.

The engagement was a victory. Soon into the battle of Africa the air forces of the United Nations put the 37 mm. cannons of America's Bell Airacobra, and the massed cannons of the deadly twin-engined Lockheed Lightning and the British Beaufighter. The British ordered more of the Hurribusters, and the tank strafing by airplane became an accomplished fact. In April 1943 an announcement in the London Gazette, Britain's official publication which announces decorations for valor, stated that an R.A.F. pilot had been awarded the D.F.C. for destroying nine tanks from the air during the 8th Army's advance towards Tunisia. Those 40 mm rapid firing guns had been deadly enough to justify the lengthy and painstaking experiments that brought the tank-busting planes to reality.

The success of the Hurribusters revealed that American and British Air Forces had ganged up against the tank in a big way. In North Africa squadrons of Hurribusters, Kittybombers (P40's), Bostons, Beaufighters, Lightnings and Warhawks went into action on a carefully worked out plan. Each particular type of plane had its own special function in the attack. The light bombers con-

centrated on supply dumps and troop concentrations, the Lightnings and Airacobras took on the tank supply vehicles and workshops, while the Hurribusters and Beaufighters dealt with the tanks. The A20's dropped calling cards in the form of parachute bombs, one of the deadliest weapons that can be used against ground forces. These concentrated attacks wiped out not only the tanks, but their vital life lines of supply and repair. Without their mobile shops and their gasoline the panzers that survived were easy victims for the British tanks, or for the low flying pattern bombing which the British humorously called Boston "tea-parties."

Nothing was left to chance in the planning of these raids. The Warhawks kept the German planes at bay, the light bombers joined in strafing the troops and vehicles after they had laid their eggs. Usually the German vehicles scattered in wide circles into the desert to escape the devastation of the concentrated air blows. After them went the Beaufighters and Lightnings, which had covered themselves with honor in this particular kind of work. An armored vehicle or transport truck has little chance of survival from an attack by these machines which pack a terrific fire punch. Both types have destroyed tanks with their cannon and machine guns.

The Beaufighter, originally designed for night fighting, carries four 20 mm. cannon and six machine guns. The impact of a short

THESE ATTACKS WIPED OUT NOT ONLY THE TANKS BUT THE LIFE LINES OF SUPPLY.

burst from these guns is sufficient to disintegrate any vehicle short of a heavily armored tank. The arrangement of the bullet group or field of fire of the guns gives the pilot a far better chance of scoring a damaging hit than if he had only one gun at his disposal. There are many patterns or bullet groups, the usual one being a triangle ten feet high with a ten foot base, or an oblong covering a similar area. In going in to attack a target, from an angle say of thirty-five degrees to the ground, the area of fire is considerably increased (see diagram). In the case of the Beaufighter the light machine guns deliver some 160 rounds a second, while the 20 mm. guns pump out their shells at better than four per second. If the pilot is anywhere near his mark something is bound to get hit, and few motor vehicles survive an attack.

The enemy, however, was answering back, and began to fit heavier anti-aircraft defenses to his tanks, as well as to escort his mechanized formations by mobile anti-aircraft guns of varying calibres. These ground defenses called for special tactics on the part of the attacking tank-busters and vehicle strafers. It is well known that an airplane flying in a straight line, even at all-out speed is a fair target for a good marksman with a modern gun-sight.

Pilots engaged in this work therefore learned to approach their targets on an irregular weaving course, shaking violently until the last few hundred feet of approach when they straightened out and took aim. Sometimes they would go in, deliver a burst, zoom, to change altitude, then half roll, deliver a burst from an inverted position, complete the maneuver and finish the job with another burst of fire.

In the meantime the Russians had already developed their own special method of dealing with tanks from the air. At first they followed the French scheme of sending hurriedly constructed, heavily armored planes fitted with 30 mm. cannon, firing a high velocity armor piercing shell. These were successful, but the rate of destruction was not fast enough, and into the battle the Red Air Force flung their most formidable weapon, the Stormovik, equipped with the same calibre cannon, four 50-calibre machine guns, and a deadly weapon known as the racket bomb. These projectiles are self-propelled by a rocket charge as they leave the machine. The bombs worked on the principle of the dive bomber, but they did not depend on gravity and the speed of the dive for their penetrating power. Instead, the rocket charge gave them stupendous penetrating power. The Stormoviks,

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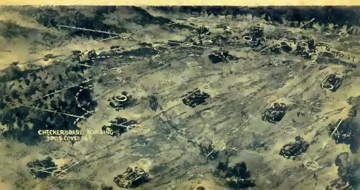


SO EFFECTIVE WERE THESE WEAPONS THAT THE GERMANS NAMED THEM "BLACK DEATH."

manned only by the pilot, come into attack at low level The pilot sights his plane as does the pilot of a dive bomber. Then, as he fires his guns to check his aim, he releases his deadly bomb that gains a terrible velocity as the charge explodes. No tank could stand against it. So effective were the weapons that the Germans named them "The Black Death."

The early model Stormoviks were equipped as tank-busters only, but later models were so equipped as to be self-defensive. With a higher powered engine and additional machine guns the pilots were able to take on the German ME 109 G's, the standard fighter used by the Luftwaffe against the Russians

So heavily armored are these remarkable machines, that German correspondents reported that 50- and 30-calibre machine gun bullets literally bounced off them as they came into attack

The Stormovik is probably the most successful all-round machine produced by the Russians. It is largely responsible for the ever-increasing number of tanks being destroyed by Stalin's armies as they continue their offensive, and as yet the Germans have found no answer to its devastating attacks Stalin awarded its young designer a prize of 200,000 rubles

At the beginning of the fighting in North Africa it was thought that the dive bomber would be the master of the tank The British soon found that its vulnerability to fighter attack proved otherwise Similarly it was an easy target for ground based anti-aircraft fire when in its final dive By spreading tanks and vehicles over a wide area, the effectiveness of the attacks was nullified.

Low-flying horizontal bombing proved far more effective Two types of bombs are used in the normal attack These are the fragmentation bomb fitted with a rod which explodes the fuse on percussion and spreads the blast over a wide area, and the small high explosive bomb dropped in trains on a predetermined pattern A squadron of planes flying in formation can cover a large area in such a way that hits or near misses can be scored on practically every vehicle. Tanks are as susceptible to near misses as ships Air Marshall Tedder's "Boston Tea-Party" bombing followed this theory. Dividing the target to be bombed into checker board pattern, the A20's (Bostons), Mosquitos and Hurribombers dropped their bombs in such a way that every square of the checkerboard was overlapped with the explosions of the bombs dropped on its neighbor. In this way huge areas of territory could be cleared of enemy tanks.

Another deadly weapon used against tanks and motor vehicles were the U. S. Army Air Forces Parachute bombs, dropped by A20's and other medium bombers These bombs have no stabilizing fins as do the normal type of bomb The parachute that brings them to earth at a speed of about 25 mph acts as a stabilizer The airplanes fly low over the target area, and strew a trail of the

bombs, ahead of the advancing vehicles In a concerted attack the air above the tanks is full of these deadly floating missiles, and according to reports and pictures from the battlefields, the destruction caused by this form of bombing is exceedingly high

We see then that by means of gun and bomb the airplane has become the tank's most deadly enemy Today military authorities consider that the tank is now destined to play a new role in warfare, that of supporting infantry and mechanized troops instead of leading the assault as exploited by the Germans in all their offensive campaigns

Even in such a role, however, the tank is not safe from its enemy. The aerial tank-buster such as the Stormovik and the Hurricane II-D can search it out, and deal with it as surely as the U. S. Army's Bazooka which seems to be the answer to the best tank at close range.

The battle will continue, however Heavier tanks with greater anti-aircraft protection and heavier armor will put in their appearance That will call for heavier fire-power on the attacking planes The tank is on the defensive at the moment, but the designers may pull an offensive device out of the hat at any moment, and force the airplane to go one better.

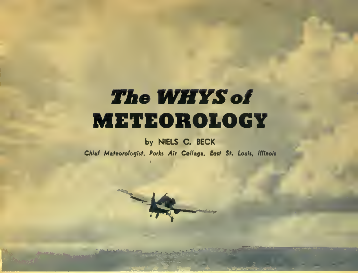
In battling with the heavily armored tank, the airplane has had a great advantage. The designers have learned that it is possible to put heavy calibre guns in airplanes. Shortly we may hear of really big fellows in use With more and more armor going into heavy bombers, the use of a rocket gun firing a 75 mm shell or better may be the answer. The principle of modern war is roughly "What fights must fly." The Stormovik would seem to be almost a flying tank To destroy a flying tank there must be a flying tank-destroyer That is how things go in war.

In the meantime the aerial tank-buster is tops, but fliers are wondering what those 40 mm cannon of the Hurricane II-D's would do against a heavily armored bomber One burst, they say, would be enough Although the enemy may succeed in building an answer to our "Forts," we can rest assured that we also have plans for greater "Forts" The war in the air is being fought not only by pilots but on drafting boards too

The WHYS of METEOROLOGY

by NIELS C. BECK

Chief Meteorologist, Parks Air College, East St. Louis, Illinois

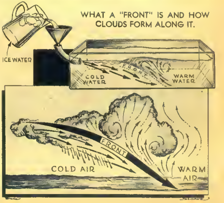


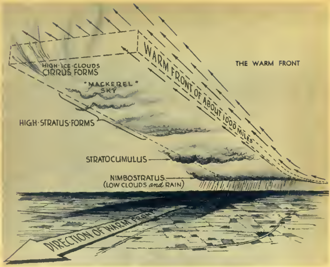
Do you think you might like to become a meteorologist? This article will help you to decide.

HAVE you ever gazed into the clear depths of a woodland pool? In spite of the first apparent stillness and glass-like transparency of the water you must have eventually observed the presence of small eddies and whirls where movement was creating such changes in fluid density that the eye was able to detect it. Moreover, any large scale movement such as a flow of air rippled the mirror surface into countless little wave crests and troughs. The analogy between water and the fluid air of our atmosphere is not new, nor is it entirely accurate, but it does lead to a more graphic understanding of the whole subject of the atmosphere.

The movement of air is not accompanied by such large density changes as to make them immediately evident, but the trained observer sees many things that the layman overlooks.

WHAT A "FRONT" IS AND HOW CLOUDS FORM ALONG IT.





WARM OCEAN AIR FROM THE SOUTH may be swept up and over stationary cool masses with forward edge of warm current being marked by delicate cirrus etchings. These give way to an evolutionary series of all cloud types, down to possible presence of fog at ground, where warm air first begins its ascent up and over cold air.

All of us have noticed the shimmering effect of rising air over a hot pavement on a summer day. But how many have watched cloud forms for the stories they tell about moving air?

In a very real sense, clouds are air waves in which the vertical wave movement has cooled the air until its water vapor has been forced to appear as liquid water in a multitude of cloud droplets. The amplitude or depth of the wave is also revealed in the cloud form.

On cloudless days or days when smooth flat stratiform clouds appear, the air is usually smooth; but go aloft on a day when great cumulus plumes fill the sky, and you can assure yourself of a ride that will remind you of that fabulous rocky road into Dublin. Vertical air currents will buffet your craft at all levels and you will find that a thousand gremlins will try to pull the stick from your grasp.

In a larger way, cloud waves mark the forward edge of the great air currents that make world weather. As cold Canadian air begins its periodic mass flow into the United States, the forward edge of the current is defined by clouds in the air that it is lifting and displacing, until finally the forbidding cumulonimbus or thunderstorm clouds may appear, to advance in a solid line south and southeast and worry the airmen who must penetrate it to complete their appointed rounds.

The drawing shows how cold water pushes under warm water, making a plow-shaped "front." In an identical manner, cold air plows under warm air, lifting it up and condensing it into cold front cumulus cloudforms. Invisible as a front may be, it becomes visible through its cloudform which may be likened to the whitecaps upon a current of water. Wherever one air mass invades another, the disturbance along the front creates typical cloudbanners — identifications that even the layman can recognize, once he has learned to "see" air.

In a similar way, warm ocean air from the south may be swept up and over stationary cool masses with the forward edge of the warm current being marked by delicate cirrus etchings, which give way to an evolutionary series of all cloud types, down to the possible presence of fog at the ground where the warm air first begins its ascent up and over the cold air. Notice in the drawings

of the cold and warm front models how the air currents rise.

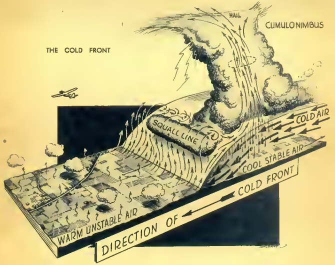
Again, in all these cloud forms, the intensity of air flow is readily apprehended. When flying in the overcast in such disturbances, the air will be found to be smooth and comfortable in clouds with a smooth flat top and base, but let the airplane enter a cloud deck seething and boiling with swelling top and base and the pilot and his passengers are in for a very rough time of it. The chaotic and turbulent appearance of clouds is heavy with significance, for it is nature's way of telling you that they spell trouble for airmen. It should also be remembered that it is under just such conditions of cloud turbulence that winter-time icing may be most severe and dangerous.

Vertical currents of better than 50 m.p.h. have been found in certain turbulent cloud types, especially cumulonimbus, and, of more importance, these currents move both up and down. Imagine an airplane flying along in an "up" current of 40 to 50 m.p.h. with the ship trimmed for as near to level flight as such a condition will permit. Then imagine the forward half of this same airplane being thrust into a "down" current of 40 to 50 m.p.h. Thus you have some idea of why large airplanes have been virtually turned turtle in severe thunderstorm activity with the pilots almost helpless to remedy the situation.

The next time that you go out under a star-filled sky on a cold winter night, look up and see what your eyes tell you. If the myriad lights are comparatively steady with only the dimmest of them twinkling, then you will know that the great body of air over your head is still, and all is well. But, if every star in the heavens seems to twinkle and dance so that the air looks alive with the same eddies and whirls you watched in the woodland pool, you may be sure that another weather drama is in the making and that the great currents of air are trying to tell you so as they race along the upper levels of the ocean of our atmosphere.

In future issues of FLYING CADET you will be introduced to air flow, the atmosphere, temperature, winds—all the various phenomena that go to make up weather.

When this series is complete, you will have more than a nodding acquaintance with weather—and you will surely know whether you want to make a career of meteorology.



ON DAYS WHEN GREAT CUMULUS PLUMES FILL THE SKY, when you go aloft, you can assure yourself of a ride that will remind you of that fabulous rocky road into Dublin. Vertical air currents will buffet your craft at all levels and you will find that a thousand gremlins are trying to wrest the stick from your grasp.

THE HELLCAT *bares its claws*

SOMETHING new and devastating has been added to Uncle Sam's amphibian striking power. This is the Grumman F6F (Hellcat) fighter plane, son of the famous Wildcat which in the opinion of Mr. James V. Forrestal, Under Secretary of the Navy, saved Guadalcanal. From Pearl Harbor through 1942 the sturdy barrel-bellied Wildcat designed in 1937 became a legend in the Pacific. Although slower and less maneuverable than the fragile Jap Zeros they definitely proved the superiority of American pilots and American material. In one dog fight over embattled Guadalcanal, twenty-eight Wildcats shot down thirty Zeros with a loss of only three of their number. It was in these deadly little ships that U.S. Marine Corps ace Major Joe Foss shot down 26 Japanese planes in less than three months, and in a Wildcat Lieutenant Commander "Butch" O'Hare fought and butchered six out of nine Jap bombers single-handed.

During the early stages of the North African campaign the Navy Wildcats operating from U.S. carriers won control of the air against the Vichy fliers.

But the Wildcats were old ships, outmoded and undergunned. The pilots knew it. They knew, and some of us knew, that something new was coming, a super plane with all the good qualities of the Wildcats and with something added, greater engine power, higher fire power, greater speed and altitude than the planes they flew.

LEROY C. GRUMMAN
President of Grumman Corporation

One morning almost a year ago I saw the new machine the Navy fliers were expecting, and learned the story of its creation, which is a tribute to American enterprise and efficiency. In appearance it looked like a Wildcat with the familiar square-tipped Grumman wings that can be folded back for storage. There was the same dumpy Grumman fuselage, the distinctive Grumman keel and into its slightly increased dimensions the designers had built an astonishing number of improvements.

The actual details of the new wonder fighter are a secret. I can say that it is powered by a better than 1200 h.p. Pratt and Whitney rotary engine designed especially for high altitude work. Its landing gear is wider than that of the Wildcat. This gives a greater margin of safety by insuring stability on take-off. Its range is considerably longer than that of existing fighter planes, and an additional belly tank can be fitted. It has self-sealing gas tanks, a bullet proof windscreen and the armor protection of the pilot has been rearranged to give the maximum amount of efficiency.

One of its outstanding advantages, according to officials of the Grumman Company, is that it can turn inside its elder brother the Wildcat in a dogfight. Also

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the pilot has increased visibility, and the ship carries considerably more ammunition for the deadly 50 calibre guns

This is how the Hellcat was born The Navy pilots who battled the Japs in the early days of the Pacific warfare, were enthusiastic over the performance of their Wildcats, but the faster more maneuverable Zeros showed their limitations. As a basic design the Wildcat was superb, the best ever, the fliers declared. If it could be given an improved all-around performance there would be nothing to touch it. The Navy passed their opinions to Mr. Leon Swirbul, the dynamic vice-president and general manager of the Grumman Company He consulted Mr. Leon Grumman, the company's president and Mr William T Schwendler, the chief engineer Mr. Swirbul flew to Pearl Harbor after the Battle of Midway to obtain first-hand information from the little band of fliers who had socked the Japs so hard. He listened to everything the boys had to tell him, the good with the bad He made a comprehensive list of their suggestions, he heard their problems. Particularly interesting were the suggestions of Lieutenant Commander Thatch USN, who evolved the famous Thatch weave by means of which the slower Wildcats had persistently clawed the Zeros from the skies. "We want more speed, more climb" was the sum total of the suggestions. Swirbul came back to America and the all important task of modification got under way

In creating the new fighter plane the Grumman engineers had one outstanding factor in their favor They knew they had a good basic design, just as had the British in Mitchell's original Spitfire, and Camm's early Hurricane The Wildcat had been thoroughly combat tested. Reports were available on every type of damage sustained by the F4Fs (Wildcats) in combat.

By October 1942, the new design was complete, and the machines were coming off the production line even before the factory building in which they were being assembled was finished. Early machines were sent to Navy experimental squadrons for tests. Some were delivered to the British Navy, who sent enthusiastic reports of their performance.

On September 1, 1943 the Japs felt the claws of the Hellcat for the first time over Marcus Island The result of the combat was an overwhelming victory for the American fliers With its greater speed, faster rate of climb, increased armor and unbelievable maneuverability the Hellcats completely outclassed the new Jap Zero (The Hap) a far less vulnerable and more heavily armed version of the original

During the Navy's attack on Marcus Island, which lasted for nine hours, the attacking planes fired 150,000 rounds of 50 calibre ammunition The island's defense guns were silenced and two-thirds of the island's garrison were probably killed

The designer's work was justified. They had given the Navy and Marine fliers the punching power the boys had asked for.

There is something wicked looking and exciting in the appearance of this fighter plane The slant of the fuselage, the long nose housing the powerful motor, the shining blades of the propeller and the blunt noses of the big guns protruding from the leading edge of the wings help to give this impression. The dull gunmetal blue color, the rounded torso of the fuselage, the deep barrel snout of the cowling complete the picture of a dangerous heavyweight killer.

On the ground the Hellcat is as exciting a thing as you could dream of In the air it becomes a roaring deadly beauty, flashing through the sky in graceful arcs at a speed that worries your eye and does something to your breath. It makes miles into seconds, and seems to climb at the same speed as some fighter-planes can dive Everywhere about it is the suggestion of formidable power and ruggedness

In a demonstration by Grumman test pilots, a few of us saw the new machine put through its paces. The big fighters roared, zoomed, dived and twisted at ferocious speeds One of the pilots demonstrated the efficiency of the ship for ground strafing. Using the latest methods of approaching the target, he dived, and "fired," then climbed, half rolled, "fired" on the target from an inverted position, completed the turn and "blazed" again To hit an airplane moving in three directions at the same time would be a severe test for any gunner.

At the end of each maneuver demonstrated by the pilot the guns of the aircraft could have delivered bursts of fire sufficient to destroy the target.

Ground strafing has been developed into a fine art, after experiences in the Pacific and in Africa. The Hellcat and the Wildcat are both well suited for this, particularly because the pilot is placed in the top of the round part of the fuselage where he can see over the plane's nose In the Hellcat his view is further improved by the slope of the engine cowling

With its companion, the 2000 h.p Vought - Sikorsky Corsair, the new Hellcat gives the U S Navy the two most outstanding carrier fighter planes known to exist Reliable experts state that it is unlikely the Japanese will be able to produce any plane to approach the performance and ruggedness of these two planes, both of which have a superiority in fire power over existing Jap

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FORMATION OF HELLCATS looking for trouble. Woe to the unfortunate Japs who are doomed to a showdown with these new Navy planes.

HELLCATS ON CARRIER DECK. First photo released which shows group of Hellcats and TBF Avengers on carrier, moving up for take-off

gallant fliers with fighter planes that can fly faster and further than the rest. Remember this in considering our coming struggle with the weakening air power of Nippon. A better machine flown by a disciplined and adequately trained pilot will score a victory over an inferior machine. Even though the pilot of the latter may be as well trained, if he is out-maneuvered, outgunned and out-climbed, he is as good as lost. When we consider that the 1937-designed Wildcats, modified only by the addition of extra guns, are credited with knocking down ten enemy planes for every Wildcat lost in combat, we can expect the Hellcats and the Corsairs to make a substantial increase on this ratio.

Naval experts make no secret of the fact that Japan is counting on the great distances of the Pacific to protect her homeland, and the possessions she has seized. This advantage is lost to her, however, if our fighter planes have a longer range, and can carry their superior firepower to her own territory, while the aircraft carriers from which they fly circle safely out of range of the enemy's aircraft.

To get farthest, fastest with the biggest punch is the creed of the carrier-based fighter plane. The Hellcat lives up to that creed.

fighters. Reports from the Pacific say that "Hap" (the Navy term for the new Zero fitted with 20 mm. and 15 mm. guns) is a better plane than "Oscar" the original type, but say the fliers, "It explodes just the same" when hit by 50 calibre guns.

The last round of the final showdown in the Pacific is likely to be one of air-power, in which the new fighter planes will play a dominant part, both in escorting torpedo and dive bombers attacking Japanese naval units, and in attacks on islands such as Marcus and Wake. Once these islands are captured they can be used as bases for the deadly land-based torpedo bombers, and the heavy long range super bombers.

But first our carrier-based fighter planes must clear the air. Without superiority in fighter planes the U.S. Navy cannot tackle the menace of the Japanese fleet. Air power alone cannot win a sea-battle, but without air superiority even the heaviest task force would be at a terrible disadvantage.

The U.S. Navy knows this, and that is why it has provided its

HIGH OVER THE CLOUDS, Grumman Hellcat fighters stalk their prey. Dangerous killers, these, ready to pounce at the first sign of enemy ships.

'WHISTLING WILLIE' CLEARS THE BURMA ROAD

BY ROBERT OLIVER

LATEST of the aviation stories from the fighting fronts is one about "Whistling Willie," a flame-spouting banshee that cleared the Burma Road of Japs for three days. The Japs termed "Willie" a new "aerial weapon designed foolishly to unnerve the Emperor's conquering pilots who hold mastery of Burma's skies."

Radio Tokio went on to say that the "secret weapon spouts streams of flame and screeches in horrible tones as it flies."

But the real story, as told by Wm Van Dusen, New York representative of Pan American Airways, disclosed that "Whistling Willie" was just one of Pan American's China National Airways transports that was armed but a bit battle-scarred.

It all began one dark night when a CNAC DC-3 transport, crowded with refugees and fleeing from the battle zone, ran into trouble. Shuddering as if it would break out of its nacelle, the left outboard engine sputtered and died. Captain Harold Sweet, of Los Angeles, landed the craft just over the border in Free China, into which he managed to slip.

Quick inspection showed that the engine's damage was beyond the ability of the flight crew to manage. They'd have to get some help.

Meanwhile the ship was in dire danger of attack by the Japs. The 54 passengers clambered out and began covering the craft with brush while Sweet drained gas and oil from the tanks. He then sent a radio call to CNAC's headquarters at Chungking for help. He took the passengers to a nearby village, then started out to enlist an army of coolies to help in rolling the ship off the field.

Before they could move the craft, however, the Japs had found their target. Streaking out of the dawn five Mitsui fighters lined up, one behind the other, and machine-gunned the helpless hulk until their ammunition was exhausted. They left her riddled with bullet holes, but thanks to Sweet's foresight in draining the tanks she didn't catch fire.

Other fleets of Japs also came over for target practice, leaving the ship a shambles. Before dark the same day, the repair crew arrived. By that time, the coolies had dragged the wreck off the little field to the sheltering branches of a clump of bamboo trees.

From wing tip to wing tip, from nose to tail, Sweet counted 3,247 holes. The instrument panel was shot away, control wires were severed, fuel tanks were like sieves, all the glass was blown out.

Makeshift repairs were made, but the big question was how to patch the holes in the craft's skin. The repair crew had brought enough metal to cover holes in the vital surfaces. But that left nearly 3,000 others. A canvas awning borrowed from a missionary's garden and a jug of homemade glue finally did the trick. Little cloth patches were cut out and pasted over the holes.

The ship took off with the mechanics and headed for a refueling point just north of Burma en route to a safe port in India, 1,500 miles away.

During the trip, however, they ran into a storm which didn't add to the peace of mind of pilot and passengers. The engines were running roughly, due to incomplete repairs, and long streaks of flame shot back from the exhaust stacks. The engines hummed a raucous baritone, but suddenly a shrill "ping" broke the sound pattern. Almost immediately another ping and another note. Then a thousand pings and a thousand discordant notes screeched and whined and wailed about the ship.

When their hearts stopped jumping and they got their breath back, the crew and passengers realized what was happening. The rain was washing off the canvas

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patches and each uncovered hole produced a new and shrill note.

There they were, burrowing through the night, a weird cacophony of wild shrieking tones, their motors shooting back long streamers of flame.

Suddenly, off to the left, the pilot sighted a fleet of six planes. A Jap patrol On and on they came and then, inexplicably, the Japs wheeled about in tight formation and streaked in the opposite direction.

Two hours later the transport landed at an Indian airport and an Army Major asked, "Whistling Willie, what have you got there? A flying calliope?" He didn't even wait for an answer "What did you radio for? We could hear you coming for the last fifty miles!"

Van Dusen's sequel is that "Whistling Willie," after terrorizing the Indian countryside from Assam to Calcutta, is back on the line again, ferrying aid to the Chinese as fast as her wings will take her Repaired, she again is as trim as a brand-new ship.

FIELD REPAIRS of AIRPLANE COVERS

Repairs, in general, include such structural work as repairs to fabric, doping, painting, changing of surfaces, replacements of struts and wires, checking and correcting alinement, repairs of fittings and nonvital structural members, replacement of control wires, thorough inspection and repairs of minor nature to hull and floats, replacement of tail skids or wheels and minor repairs to landing gear, adjustment of brake assembly and replacement of parts Minor repairs to powerplant include cleaning of cowling, fuel and oil systems, replacement of hose connections, replacement or minor repairs of engine accessories; changing of propeller blades; replacement of defective instruments

Repairs are classified as urgent or desirable and as minor and major

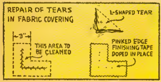
Holes and tears can be patched and recovering of fabric surfaces consequently obviated, provided such damaged surfaces are otherwise tight and in good condition

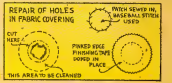
Rips or tears are cross-stitched as shown in the accompanying figure, before cleaning oil, dirt, and other foreign matter from the damaged area

Dope solvent then is applied and the foreign matter and softened dope scraped off with a blunt tool such as a putty knife over an area covering at least 1½ inches from the tear A patch of grade A cotton tape is usually employed For longer tears, oblong patches with square corners, frayed, about one-fourth inch all around, should be used, both owing to the area which can be covered and the adhesion afforded the edges by the fraying Dope then is worked into and around the tear after which the patch is doped and applied over the tear with the warp of the patch coinciding with that of the surface covering as nearly as possible After rubbing the patch with the hands until smooth, dope is applied over it and when dried, the finish coat is put on.

Holes are patched in a manner similar to the above except that after the jagged edges are trimmed, a piece of fabric of the same contour as the hole is whipped into the place to fill it as shown in the accompanying figure

Whenever possible, ribs should





be repaired by the ramoval and replacement of all dameged members. The fabric must be cut away and laid back to enable the machenic to get et the work. Care should be taken not to cut away the fabric any further than nacessary, and it should be done in e manner which will make possible the neatest and strongest patch.

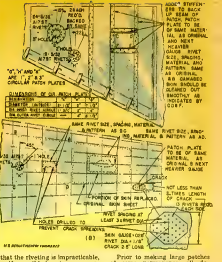
Replacement of Rivets Periodic removal of aluminum alloy rivets in airplanes will be found necessary as corrosion, sustaining of shocks, and vibration cause defects about these members. Rivets to be replaced must be carefully drilled out. The holes must be examined for roughness, roundness, and if out of round should be reamed out to take a largar rivet size. Rivets should, if possible, be procured anodized. The subsequent heat treating and driving does not destroy the protection afforded by the anodic film.

Before the rivets are driven, some kinds must undergo heat treatment. Rivets in all sizes up to one-quarter inch in diameter (which are generally of 17S alloy) are heat-treated to 505° C. (940° F.), quenched in cold water, and must be driven within one hour after quenching. Rivets not used within this hour must be subjected to another heat treatment.

In making repairs in the field, usually it is impracticable to carry out the heat treatment necessary for the proper preparation of aluminum-alloy rivets. The use of bolts for replacement of drilled-out rivets then will be required as a temporary measure. In addition, riveting of certain portions of assemblies is impracticable because it will be found impossible to insert and hold in place any form of tool for backing up the rivet. Placing other metals in contact with aluminum alloy causes complications The most active corrosion results from placing aluminum alloy in contact with copper or steel in salt atmosphere, although the corrosion is not as active in the case of steel. The bolts used, therefore, should be of aluminum alloy. They should be round-head bolts, and an aluminum-alloy washer should be inserted under the nut.

If aluminum-alloy bolts are not available, steel bolts may be used in an emergency, but they must be replaced at the earliest opportunity.

If, after drilling out a rivet, it is found that the metal in the vicinity of the periphery of the hole is corroded to an extent that, after cleaning, the hole is enlarged so



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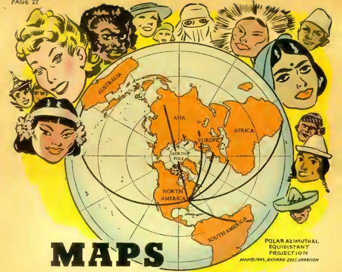
that the riveting is impracticable, or if a small hole is in some manner made in the aluminum alloy sheet, repairs may be made by patching. A typical patch is shown in the figure.

The filler washer is cut from sheet to fit the hole being patched. Its function is to act as a filler and so prevent the cup washers from being subjected to excessive bending stresses. The cup washers are cut from heavy gage sheet. The lower one is of a size sufficient to allow ample faying surface all around the hole. The upper one should be of the same size as the lower, if possible, but its size and shape will be governed by the proximity of structural members.

Repair of any but small holes by the use of this type of patch is not advisable. When the area involved is at all extensive it is better practice to remove the section affected and replace it with a new section. Large patches, of course, may be used in emergency, but the section should be replaced at the earliest opportunity as it is certain to leak and cause further trouble.

Prior to making large patches of some permanence, all deformed, cracked, or dented metal should be cut away to leave a large circular or square opening. The metal sheet is cut readily with small curved tin snips, after which the free edges should be filed to eliminate burrs and unevenness. A piece of metal similar to that of which the sheet is composed is cut to the same shape as the hole after it has been enlarged with an allowance of about 1 inch all around for rivets. After the piece has been cut to shape, the rivet line is marked around the periphery and rivet centers are indicated with a center punch. When rivet locations are indicated on the patching piece, it is placed over the hole, and holes are drilled through the sheet patch and the ruptured sheet simultaneously.

A few machine screws are used to hold the patch in place for riveting. A dolly bar is used on the inside to rivet against and rivet sets are used to give a neat round head, though they may be peened flat with a hammer.



MAPS

. . . for Global Peace

NO SPOT ON EARTH IS MORE THAN 60 HOURS FLYING TIME FROM YOUR LOCAL AIRPORT

JUST as Columbus changed the geography of his day when he sailed off the edge of the world, the airplane is changing our world.* We are beginning to think of the earth more and more as the round sphere it really is—a sphere surrounded by a navigable ocean of air several miles deep. We are turning more and more to the globe—and to maps which are projected in such a way that they show true distances. For distances have become so short, because of the plane, that they are much more important to us than they used to be. There are no longer such things as barriers—not when the Atlantic has dwindled to the size of a mill pond that can be crossed in 400 minutes of flight—not when mountains, to the airman, are almost as level as if they didn't exist.

So, in addition to the Mercator maps, which commonly have been used for the study of geography and show us old established surface routes, we now want maps which are keyed more closely to the approaching global peace—maps which show airline routes as straight lines that can easily be measured. Fortunately, there are such maps.

The map which best shows us the actual relationships of the earth's areas from any given point is one with a rather frightening name. It is called an "Azimuthal Equidistant" projection. In simple language, that merely means a map which is centered on a definite spot on the globe, and on which the distance to any or all other points on the globe can be accurately measured. On this map, a straight line connecting the *center of the map* with any other point on the globe is a great circle course—the shortest distance between those two points.

An Azimuthal Equidistant map can be centered on any given point. Compare a projection centered on Washington, D. C. with one centered on the North Pole. Can you see how it differs?

The most common form of this map is the polar-centered map with the North Pole as the center.

There is a good reason why this map is being used more and more. As you know, the bulk of the earth's land masses lie north of the Equator. So, a map with its

AZIMUTHAL EQUIDISTANT PROJECTION, *centered on* WASHINGTON, D.C.

center at the North Pole enables us to see with some accuracy three-fourths of the earth's land area, on which 90 per cent of the earth's people live.

Such maps show us some very interesting facts about this new world we live in. At last—on an Azimuthal Equidistant map—"as the crow flies" takes on new meaning and the shortest distance between the center and any other point can be shown by a straight line.

For example, look at the map which is centered on Washington Airline routes, to any city in the world, can be shown on this map as straight-line, measurable distances like the spokes of a wheel, radiating from the hub, which is Washington. When we attempt to show the same airline routes on a Mercator map, the shortest distance lines between two points are curves, because of the distortion of values which is inherent in the Mercator projection.

Distorted as it is, however, the Mercator map does help the navigator, for on the Mercator map a straight line between two points is a true bearing.

A Gnomonic projection of the North Atlantic area appears to be one of the most distorted maps ever devised. Yet it is extremely useful for aviation, since any straight line on a Gnomonic projection, from any one point to any other point, is a great ciacle course. One of the limitations of the Gnomonic projection is the fact that less than half the world can be shown at one time.

Now we begin to see why we must use different maps for different purposes. Look at the Mercator projection on which the map-maker has traced the surface route from New York to Hawaii, then to the Philippines, and across China to Chungking.

When we try to show the direct airline route between New York and Chungking on this map, we discover it can't be done. The airline route, represented by the dotted line, behaves in a most peculiar manner. It disappears off the upper edge of the map and cannot be seen again until it drops down over the top of the map, farther to the West, into China. This illustrates why the Mercator projection is hardly suitable as an accurate map on which to show direct airline routes.

Now the map-maker shows us the airline route from New York to Chungking on an Azimuthal Equidistant map centered on Fairbanks, Alaska. Here we see how a plane would hold its course right "on the beam" from New York to Fairbanks and then on to the Chinese capital.

On a North Polar Orthographic map, we get a small variation. Now, the shortest-distance course must be shown as a gentle curve, because the center of the map is not on the route. However, if the pilot wished to by-pass Fairbanks on a shortest-distance course from New York to Chungking, his plane would fly almost directly over the North Pole, as

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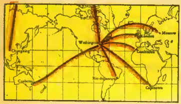
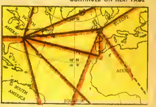
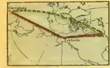


MERCATOR PROJECTION



GNOMONIC CHART OF NORTH ATLANTI

MERCATOR PROJECTION



AZIMUTHAL EQUIDISTANT PROJECTION *centered on* FAIRBANKS, ALASKA

indicated by the dotted red line

A similar example, not quite so extreme, shows what happens when we draw a straight line between Chicago and Tokyo on a Mercator map This line makes it appear that the shortest route travels nearly through San Francisco But the upper line, which curves toward the top of the map in a sweeping arc, is actually the shortest-distance route You'll probably say that it doesn't look right, yet it is For it traces exactly the great circle course—the shortest distance between Chicago and Tokyo, as you can see by consulting your globe

On an Azimuthal Equidistant map centered on Chicago, the great circle route to Tokyo can be shown as a straight line

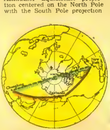
From these examples you might easily say, "The Azimuthal Equidistant map is a perfect map—a map at last to which an air-minded student of geography can turn with complete confidence to study the new global geography" But if you did, you would be forgetting the simple truth No map is perfect All maps, including the Azimuthal Equidistant map, have distortions Only the globe itself can eliminate these distortions

Because of the way in which a map-maker "skins" the globe to make an Azimuthal Equidistant projection, it is impossible to avoid serious distortions around the edge of the map.

To realize how great the distortion becomes around the edge of an Azimuthal Equidistant map, let us now look at such a projection centered on the South Pole. Although this is a very accurate map, up to a certain point, notice how great the distortion becomes beyond the equator Areas in the Northern Hemisphere s-t-r-e-t-c-h way out The continent of North America becomes so out of kilter that it resembles a long-necked prehistoric dinosaur

But in spite of the distortions of the areas on this map, it is ideal for certain purposes. For example, by drawing a straight line from the South Pole to *any* point on the map and then measuring it, you learn the exact distance to that point.

It is interesting to compare the Azimuthal Equidistant projection centered on the North Pole with the South Pole projection

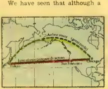


NORTH POLAR ORTHOGRAPHIC PROJ'N.

Australia, on a North Pole projection, looks as though it had been squeezed through a wringer

And this adds up to another important rule to keep in mind when studying geography Do not expect too much of a map For it is impossible to make one map do everything

We have seen that although a



MERCATOR PROJECTION

AZIMUTHAL EQUIDISTANT PROJECTION *centered on* CHICAGO

Mercator map of the world shows Greenland many times its actual size, it is nevertheless ideal for surface navigation because it shows true compass directions And we have seen that the Azimuthal Equidistant projection, while it may show some areas sadly out of shape, is ideal for finding distances, finding the shortest, most direct route between two places, or for an aviator who wishes to plot a true course and measure his distance

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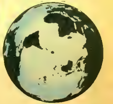
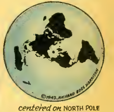


centered on SOUTH POLE



centered on NORTH POLE AZIMUTHAL EQUIDISTANT PROJECTION

from a given point. Such plus and minus qualities exist on any map that can be drawn

So we have learned that we must make special maps for special purposes And such maps are the only maps upon which we can rely to show us what we want to find out.

For example, up until now, we have been discussing maps which show us comparative distances and directions But if we wish to compare areas, or the distribution of things in various parts of the world (such as the number of telephones per square mile) we draw quite a different map of the world

Several different kinds of maps are used to show the true relative areas of the earth's surface They are called "Equal Area" maps The Azimuthal Polar Equal Area Projection is an excellent map to use in conjunction with other polar projections, where equal area comparisons are wanted

The Cylindrical Equal Area Projection is very easy to construct, although rarely used because of great distortion in the polar regions

The Aitoff Equal Area Projection shows both land and water areas correctly

The Sinusoidal Interrupted Projection is designed to show the relative areas of land masses It is often used to portray the distribution of things on land human beings, minerals, animals, etc

Goode's Polar Equal Area Projection is the least distorted in shape of all such projections shown here It is perhaps the best of all for land masses On the other hand, the best ocean map might be one centered on the South Pole, since 75% of the world's ocean aiea is in the Southern Hemisphere

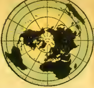
On all maps, the type of projection used should always be indicated Whenever using a map, first look for the name of the projection Try to familiarize yourself with the appearance of the various projections—and always use the correct projection for the problem with which you are concerned

This is a part of a series of three articles on MAPS which are appearing in FLYING CADET

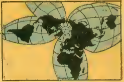
The entire series may be obtained in booklet form by writing to the Consolidated Vultee Aircraft Corporation, P O Box 157, New York City There is no charge for this booklet

EQUAL-AREA PROJECTIONS

They show the true relative areas of the earth's surface

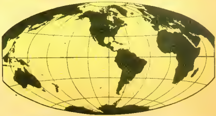


POLAR AZIMUTHAL EQUAL AREA PROJECTION

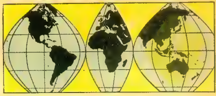


GOODE'S POLAR EQUAL AREA PROJECTION

CYLINDRICAL EQUAL AREA PROJECTION



AITOFF EQUAL AREA PROJECTION



SINUSOIDAL INTERRUPTED PROJECTION

TURBO *EXHAUST-DRIVEN* SUPERCHARGER

THE Turbo-Supercharger is a tribute to American inventive genius. It provides practically full, sea-level power up to 30,000 feet. While other altitude superchargers are mechanically driven, the auxiliary stage of this supercharger is driven by exhaust gases, instead of by power taken from the engine crankshaft.

The Turbo exhaust-driven supercharger with intercooler employs two separate superchargers. In the AUXILIARY STAGE, the *exhaust gases* from the engine pass through piping to a series of nozzles which direct the gases against the blades of the *turbine wheel*, causing the wheel to rotate. The power generated by this turbine wheel is used to run the auxiliary blower.

Aside from the obvious advantage of using the waste exhaust gases as a source of power, there is another important advantage.

The TURBINE or DRIVING UNIT has a variable speed characteristic *within itself* and so it is unnecessary to use a hydraulic clutch in order to compensate for variations in altitude.

The speed of the turbine depends on the difference in pressure between the exhaust gas and the outside air. The greater the difference, the higher the speed of the turbine and hence the greater the degree of compression provided by the Auxiliary Supercharger.

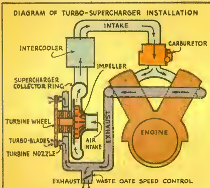
So long as we are able to get sufficient mixture into the cylinders, the pressure of the exhaust gases will remain the same, whereas the pressure of the outside air will steadily decline with altitude.

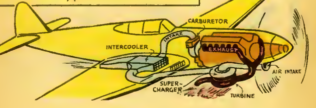
Thus, as the plane rises higher and higher, the auxiliary supercharger automatically picks up speed and provides the engine with practically the same weight of air, from sea level up to the critical altitude. The results are reflected in the chart, which shows what the 1000 H.P. Sea Level Engine is capable of doing when provided with such equipment.

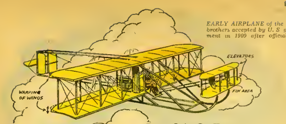
But the Turbo-Supercharger is not a "cure-all." There are disadvantages that must be weighed against the advantages. The designer is confronted with the problems of compromise.

The bulk and weight of the Turbo Supercharger with its exhaust collectors, intercoolers, complicated "plumbing" etc.,— these things greatly increase the problems of installation and limit the use of such equipment to certain types of planes.

While military restrictions prevent any adequate discussion of these factors, it may be said that for a large, high altitude bomber, the Turbo Supercharger has no equal. It also is used in fighter planes that escort the bomber, and in fighters designed to attack high altitude enemy bombers. But for medium and low altitude planes, the disadvantages are greater than the advantages.







EARLY AIRPLANE of the Wright brothers accepted by U. S government in 1909 after official tests

AERODYNAMICS

BY LIEUTENANT ALEXANDER JOSEPH
Instructor of Aeronautics
U. S Army Air Corps

HOW does it fly? What lifts it into the air? What keeps it there? Why doesn't it fall?

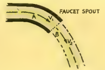
These are the questions that have been asked from time immemorial, from the littlest boy, who is satisfied to know that it flies because it has wings, to the man of science, who must know all the whys and wherefores

Through the early years of history, man wondered and asked these things concerning the birds —and since the dawn of the air age, we have been asking these very things about the man-made bird—the airplane.

It is the study of aerodynamics that answers these fundamental questions—and so, too, this study has enabled us to constantly improve our planes and to fly ever more smoothly, more freely, more perfectly.

Aerodynamics had its beginning, as a science, in the suggestions of Sir George Cayley in 1810. Cayley proposed that air be forced against the wings by moving them through the air Power for this forward motion was to be applied by means of propellers.

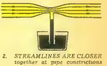
Although Henson and Stringfellow constructed successful power-driven models, basing their work upon Cayley's theory, no one contributed anything essential until 1871 when Francis Wenham devised a *cambered* (that is, curved) airfoil. The airfoil is any essential member of an airplane, usually the wing, control, or stabilizing surface, which is exposed to the air movement, in order to get a useful reaction of some sort. The airfoil is usually convex upward on the upper surface (center higher than edges) and concave on the lower surface (edges higher than center).



1 *STREAM TUBE FLOW from faucet. Length of arrows shows the actual direction of flow*

Streamlines and Steady Flow In order to understand and make use of the science of aerodynamics, it is essential that certain important scientific principles be understood.

Of basic importance in understanding air movements about a wing is the idea of "steady flow" On a windy day, you call the wind steady when at your particular locality it blows constantly from the *same direction at a constant speed.* If the direction or speed or both keep changing, you might call the wind "shifty" or "gusty" but you would not call it "steady."



2. *STREAMLINES ARE CLOSER together at pipe constrictions to show greater liquid velocity.*

Similarly a scientist calls the flow of a fluid (liquid or gas) steady if its *velocity* (both speed and direction) at each particular point remains *constant* This does not mean that the velocity must be the same at all points of the fluid

For example, if water is flowing around a bend in a pipe, the direction of flow at point B is different from the direction of flow at point A. However, if the flow is "steady" the direction and speed at point A remain fixed Similarly, the direction and speed at point B also remain fixed as time goes on At each particular point the speed and direction remain constant, although both may be different at different points

You will note in Figure 1 that lines, tipped with arrows, have been drawn out from points A

CONTINUED ON NEXT PAGE

and B and marked V_1 and V_2. The length of these lines indicates the speed and their direction, the direction of flow Taken as a whole, these lines indicate velocity of liquid flow Such a line, indicating both amount and direction, is called a *vector*

Now, imagine a line, straight or curved, so drawn in a moving fluid (liquid or gas) that at each particular point it is in the direction of the velocity vector for that particular point Such a line is called a *streamline*. If the flow is steady, the streamline through any particular point will represent the actual path followed by the fluid particles which pass through that point

Now, the amount of fluid which enters one end of the stream tube each second must equal the amount which leaves the other end in the same time This, of course, holds true of any cross section along the way Call this cross section area A and the speed of the fluid V The volume of fluid passing through any cross section in one second is calculated by multiplying the cross-section area, A, by the velocity, V, and is therefore equal to AV. Since AV must remain constant, as long as the density of the fluid does not change, it follows that if the area decreases, the velocity must increase; if the area increases, the velocity decreases.

3. *VENTURI showing throat and inlet pressure. Pressure at throat is less than at the inlet.*

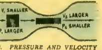
Bernoulli's principle and the Venturi Tube We have seen how the speed of a fluid varies with the cross section of the stream tubes in steady streamline flow.

According to a fundamental principle laid down by the physicist Daniel Bernoulli, *if, in a stream tube, the speed of a fluid increases at any particular point, the pressure of the fluid decreases at that point*

Bernoulli's principle is well illustrated by the Venturi tube shown in Figure 3. This is a device consisting of a pipe or tube whose cross-section is gradually reduced and then enlarged again as indicated in the diagram.

At any given time in the Venturi, the quantity of fluid passing both the inlet and the throat are the same.

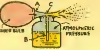
Now, according to Bernoulli's principle, the increased velocity at the throat must result in a decreased pressure at the throat



4. *PRESSURE AND VELOCITY relationships on a particle in a liquid flowing through Venturi.*

In Figure 4 the pressure and velocity relationship in the Venturi tube are indicated.

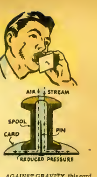
The fact that the pressure at the throat, is always smaller than the pressure at the inlet (Figure 3) makes this device useful in a number of ways.



5 *ATOMIZER Air blown in Tube A reduces pressure at C, forcing liquid up Tube B.*

A common atomizer utilizes this principle. When air is blown through the horizontal tube in Figure 5, the pressure at the connection of the two tubes is reduced, thus making it possible for atmospheric pressure to force the liquid through the vertical tube, from the top of which it is carried out by the air stream.

6a *SHEET OF PAPER is used in this experiment to demonstrate lift caused by reduced pressure.*



6b *AGAINST GRAVITY, this card is supported by the decreased pressure due to higher velocity.*

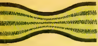
Other similar applications are shown in the example experiments in Figure 6 If the pressure is measured at a number of different points, as in Figure 7, where, due to the taper (narrowing) the velocity is gradually increasing, pressure will be decreasing.

Although Bernoulli's principle was originally developed for the flow through actual pipes, it may be applied equally well to the flow through stream tubes. In Figure 2 there is shown a flow through an ordinary Venturi tube The streamlines are shown. These streamlines may be demonstrated by constructing with flat glass sides a Venturi tube of rectangular cross section Photographs may than be taken of smoke which is being drawn through this Venturi tube. Smoke is drawn through by an electric fan The path of the smoke particles will appear as shown in Figure 8.

Water may also be sent through and colored dye injected at equally spaced vertical distances across the flow. The colored dye will form streamlines as shown in the illustration.

The walls of the Venturi tube may be drawn farther apart, as shown in Figure 9 Immediately next to the side wall, the streamlines will follow closely the contour (shape) of the wall Farther away from the side wall the streamlines will be less and less curved. In the central part

7 *PRESSURE MEASURED at various points decreases due to increased velocity at throat.*



8. *SMOKE PARTICLES passing through a glass Venturi tube will flow in streamline paths.*

of the flow the streamlines will be practically straight.

Let us imagine that the walls of the Venturi tube are moved still farther apart, one wall being moved to an infinite (greatest possible) distance from the other. The result will be as shown on the right in Figure 9. There is a curved surface with the nearby streamline following the curvature closely. Above the curved surface the streamlines are not curved as much, and at a distance equal to four times the chord length, the curvature is negligible.

Directly above the surface the gives the wing the ability to lift.

When an airplane wing is moving through the air, the pressure on the upper surface of the wing is slightly less than atmospheric pressure. (See Figures 10a and 10b.)

When the wing is tilted up (a high angle of attack) there is also a small positive pressure (above atmospheric) on the underside of the wing. Such pressure depends on the movement of air, and may be called a dynamic pressure because of air movement.

At low angles of attack, (angle between the line of the moving air and the line from the front to the back of the wing) (Figure 12), there is practically no pressure other than ordinary atmospheric pressure on the underside of a wing with a flat under surface.

Since the most modern airfoils have an under surface that is concave, there will be a small positive pressure on most airplane wings at low angles of attack.

Pressure on Wing Surfaces The pressure on each square inch of the under surface of the wing at sea level is atmospheric pressure (about 14.7 pounds per square inch). According to wind-tunnel tests on a Clark Y airfoil (Figs. 11, 12) the average pressure on each square inch of the upper surface is less than 14.7 pounds per square inch. For ex-

11 *PRESSURE DISTRIBUTION on airfoil when angle between air motion and wing is medium.*

12. *AT LOW ANGLE of attack small positive pressure occurs on concave underside of wings.*

density the force on each square foot is 23 pounds greater than on top. This is the lift provided by the wing in steady level flight and is not an uncommon value. The pressure from the front edge to the rear edge of a wing in actual flight is not constant but varies along different portions of the wing and with the velocity and the air density (See Fig. 10a.) Measurements of the pressures at various points on the upper and lower surfaces of the wings have actually been taken in flight. When the wing is tipped up so that the lower surface makes an angle of 5° to the direction of the plane's motion, the dynamic positive pressure of the air on the under surface contributes about 25 percent of

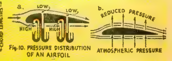


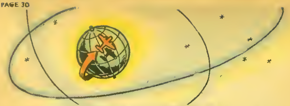
Fig. 10. PRESSURE DISTRIBUTION OF AN AIRFOIL

streamlines come closer together. This means that the velocity of the flow is greater there. If the flow represented in the center of Figure 9 is a stream of air at atmospheric pressure, then right over the surface where the velocity is the greatest, the pressure is less than the atmospheric pressure.

Now we will see why it is necessary to understand Bernoulli's principle.

It is the increased speed of the air over the upper surface of the wing that results in the decreased pressure on the upper curved surface of the wing. This ample, on a given test the pressure might be 14.54 pounds per square inch. Thus, the average pressure on the under surface must be 0.16 pounds per square inch greater than on the upper surface. This pressure of 0.16 pound per square inch, when multiplied by 144, the number of square inches in a square foot, gives for the particular speed and density a total of 23 pounds per square foot less pressure on the upper surface of the wing than underneath. This means that the force causing the lift comes from below the wing where at this velocity and air the lifting force while the effect of reduced air pressure on the upper surface provides about 75 per cent of the lifting force. It must be remembered that the weight of the plane produced by the effect of gravity, must be overcome by the lifting force before the wing will rise.

When the wing is tipped to an angle of 10° then the dynamic positive pressure of the wind on the lower part causes 30 per cent and the subatmospheric (less than atmospheric) pressure on the upper part of the wing produces 70 per cent of the total lifting force. (See Fig. 12.)



AIR NAVIGATION
FOR BEGINNERS

BY COMMANDER SCOTT G. LAMB, U.S.N.

IF you tried to pilot a plane without some knowledge of air navigation, you'd be a sure-fire target for the gremlins—and they *would* have a party! So it definitely behooves you to find out what this special art is all about!

Let's get down to serious business. Navigation is the art of determining the location of a ship or an airplane at any time, and of directing it from place to place on the earth's surface. Problems to be solved are those of position, direction and distance.

Navigation may be divided into two main branches: Geo-Navigation and Celo-Navigation (or Nautical Astronomy).

Geo-Navigation, which does not use celestial bodies, is divided into Piloting and Dead Reckoning.

Piloting utilizes the physical features of the earth to direct the plane in safety from place to place.

Dead Reckoning is that branch of navigation which utilizes such values as the direction, speed and time of flight from the last known or identifiable position.

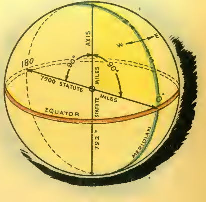
Celo-Navigation, or nautical astronomy, uses the sun, moon, stars and planets to determine position, by solutions of spherical trigonometry.

The diameter of the earth at the poles is 7900 statute (land) miles, and at the equator, halfway between the poles, 7927 statute miles.

The axis of the earth is that diameter between the poles about which the earth rotates. Its north end is called the North Pole, and its south end, the South Pole.

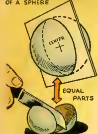
If a plane is passed through a sphere, its intersection with the surface of the sphere is a circle. If it divides the circle into two equal parts, it is called a great circle. In other words, a great circle results from passing a plane through the center of a sphere, any other circle resulting from an intersection when the plane does not pass through the center, would be called a small circle.

The equator of the earth is a great circle on the earth's surface, midway between the poles, and equidistant at all points from the poles. Consequently, the plane of the equator is perpendicular to the earth's polar axis and is a great circle.



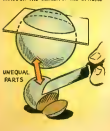
A GREAT CIRCLE

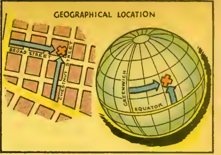
A PLANE THROUGH THE CENTER OF A SPHERE



A SMALL CIRCLE

THE PLANE DOES *NOT* PASS THROUGH THE CENTER OF THE SPHERE





We all learn direction and distance from our earliest days at school Consequently "the northeast corner of Broad and Chestnut Street, Philadelphia,' has a definite meaning to us, as also would a location on North Broad Street, exactly one mile north of City Hall.

Similarly, mariners have adopted a universal system of direction and distance which identifies location at any position on the surface of the earth. This system uses direction and distance and also the terms, latitude and longitude, to locate a position However, since the earth is a sphere, the position of any point on its surface is at the intersection of a system of circles which measures latitude or longitude

Latitude is defined as distance north or south of the equator *Longitude* is distance east or west of any fixed point on the equator Both are measured in terms of angles at the center of the earth, or, what amounts to the same thing, the length of arc (part of a circle) between the circles measuring latitude or longitude.

Parallels of Latitude are circles of the earth parallel to the plane of the equator. By definition, all parallels of latitude must be small circles except the equator, which is a great circle, because the plane of the equator is the only parallel of latitude passing through the center of the earth.

Meridians of longitude are great circles which pass through the earth's poles If they pass through the poles, their plane must pass through the center of the earth All meridians then are great circles which divide the earth into two equal parts, called upper and lower branches, by the polar diameter or axis.

A circle is divided into three hundred and sixty degrees (360°). A degree is divided into sixty minutes (60') and a minute

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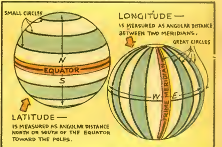


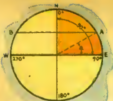


Fig. 1

into sixty seconds (60"). As we have learned, true directions are referred to as north, south, east, and west. They may also be referred to as the degree marks of a circle which represent the plane of the horizon, as shown by Figure 1 with North as 0°, East as 90°, South as 180°, and West as 270°, and intermediate directions corresponding to in-between points.

The angle NOE, between N and E, is 90° and is measured as the angle at the center of the circle between the NO and EO. Also the same angle of 90° is measured by the angular length of the arc of the circle extending from N to E.

Similarly, the angular distance of the point A above the point E is measured as the angle AOE at the center of the circle, between the lines AO and EO. It may also be measured as the angular length of the arc AE. It may be seen from the figure, that the angular distance of the line AB, parallel to and above the line EOW, is also measured by the angle "a" (AOE) or the arc AE.

The geographical position of a place is expressed by the navigator in terms of latitude and longitude.

Latitude is measured as angular distance north or south of the equator toward the pole, and is expressed in degrees, minutes and seconds of arc to a maximum of 90°. The accepted symbol of the latitude of a place is L.

The difference of latitude—DL—between two places is the angle at the center of the earth between the parallels of the two places; it is also measured as the angular length of the arc of the meridian between the parallels of latitude of the two places. For two places on the same side of the equator, the DL is the difference between their latitudes; if on opposite sides of the equator, the DL is equal to the sum of their latitudes.

Longitude is measured as angular distance between meridians and is expressed in degrees, minutes and seconds of arc. The longitude of a place is its angular distance between the meridian of the place and that meridian chosen as a reference point and is measured as East or West to 180°. It is also the arc of the equator between the two meridians in question. The accepted symbol of the longitude of a place is N (Gr. lambda).

The prime meridian, or meridian of reference, is accepted as the meridian of the observatory of Greenwich, England. Its longitude is known as 0°.

The difference of longitude—DLo—between two places is the shorter arc of the equator between the meridians of the two places. If both places are in east longitude or both in west longitude, it is the difference between their longitude, if the places are further separated, the DLo is equal to the sum of the longitude (or 360° minus the sum, if the sum exceeds 180°).

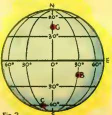


Fig. 2

Figure 2 is a representation of the earth on a flat surface. In looking at it, imagine that you see a sphere with the upper half above the paper and lower half behind it. N then is the North Pole, S, the South Pole, and E and W geographical East and West; and the semi-circle EW is the equator.

G is the position of the Observatory at Greenwich, England, the origin of longitude. Consequently, the meridian NGS is the prime meridian and it is the meridian of zero degrees of longitude. The converging arcs NAS, NBS, NGS, NCS, and NDS are great circles, and since they pass through the poles, are meridians of longitude, NAS and NBS being east of Greenwich, or in east longitude, and NCS and NDS being west of Greenwich or in west longitude.

The great circle EW is the equator from which latitude is measured.

The small circles at 30° and 60° parallel to EW, and above and below EW, are parallels of north and south latitude.

The positions of the points A, B, C, and D would then be as follows:

A—L30° N
λ60° E
B—L15° S
λ30° E
C—L60° S
λ30° W
D—L60° N
λ60° W

The difference of latitude—DL—between positions is as follows.

DL—A and B 30° N 15° S = 45° (latitudes of different names).
DL—A and C 30° N 60° S = 90° (latitudes of different names)
DL—A and D 60° N 30° N = 30° (latitudes of same name).

The difference of longitude between position is as follows:

DLo—A and B 60° E 30° E = 30° (both longitudes same name).
DLo—A and C 60° E 30° W = 90° (longitudes of different names).
DLo—A and D 60° E 60° W=120° (longitudes of different names).

A mid-latitude between any two positions on the same side of the equator is defined as the middle or average latitude between them. In other words, it is the sum of their latitudes divided by two. (The term does not apply to places on opposite sides of equator).

EXAMPLE: If one position has a latitude of 37° N and another 15° N, then their mid-latitude is

$$\frac{37+15}{2} = 26° \text{ N.}$$

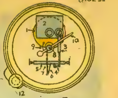
This is the first of a series of eleven articles written by Commander Scott G. Lamb, U. S. N., which will appear consecutively in FLYING CADET. All eleven parts are published in book form by the Norman W. Henley Publishing Company. Copies of AIR NAVIGATION FOR BEGINNERS by Commander Lamb may be purchased at bookstores or from the Norman W. Henley Publishing Company, 17 West 45th Street, New York City, $1.50 postpaid.

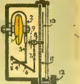
THE ANEROID BAROMETER

THE ALTIMETER IS A MODIFIED ANEROID BOROMETER

SENSITIVE ALTIMETER

1 DIAPHRAGM
2 SPRING
3 LEVER
4 LINK
5 CROSS-SHAFT
6 ARM
7 CHAIN
8 DRUM
9 HAIRSPRING
10 HAND
11 REVOLVING DIAL
12 SETTING KNOB





SIMPLE ALTIMETER

THE ALTIMETER

WHAT IT IS . . . WHAT IT DOES

ONE of the things you would most want to know if you were flying a plane is "How high am I flying?" The altimeter is the instrument from which you obtain this information.

It is urgent that you know and understand your altimeter thoroughly in order to avoid accidents. There are three definite problems faced by the pilot in which the altimeter is a critical instrument

Obstacle Clearance: If we studied the list of airplane accidents in recent years, we would find that a great many occurred because the plane failed to clear mountains or other dangerous obstacles.

Traffic Altitude: To avert collisions or traffic confusion at airports it is essential that all planes be spaced so as to allow traffic clearance

Instrument Landings. In order to effect a successful instrument landing, you must have exact knowledge of the altimeter, and of the errors which may affect its setting.

What is the altimeter and how does it work? The altimeter is an "aneroid" (without fluid) barometer, a mechanical instrument which measures the pressure of air and shows this pressure in terms of feet of altitude

Back in 1643, the inventor of the simple mercurial barometer discovered that AIR PRESSURE DECREASES WITH ALTITUDE. For each 1000 feet of ascent, the mercury in his barometer fell approximately one inch, denoting a corresponding decrease in pressure, This is actually true for the lower levels of atmosphere, but as we go higher, the air is lighter and less dense, and a greater height must be reached before there will be a one-inch fall in the barometer

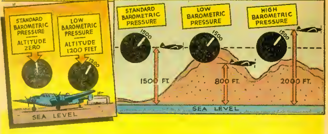
The aneroid barometer is composed of a metal box or diaphragm, which has been pumped to a good vacuum and sealed. This box tends to contract under an increase of external atmospheric pressure or to expand under a decrease of pressure. The small contractions or expansions are amplified by means of levers and extremely small special gears and the motion is transmitted to the dial hands by a chain or series of links. There is a strong spring attached to the box, which keeps it from collapsing under a great change in pressure A hairspring is also attached, to help return the needle to its normal position

An altimeter is a sensitive aneroid barometer. The sensitive altimeter dial has a "minute hand" which registers hundreds of feet of altitude, and a smaller or "hour" hand which shows thousands of feet. That it is exceedingly sensitive is apparent if you consider that a contraction of less than $\frac{1}{16}$ of an inch will cause the large dial hand to move around 35 complete times The altimeter scale

CONTINUED ON NEXT PAGE

is calibrated according to "average" or "standard" conditions. When a change in pressure occurs, the altimeter registers the altitude which would produce that change *under standard conditions*. As "standard conditions" it is assumed that the temperature at sea level is 59° F and that there is a decrease in temperature of 3.6° F for every 1000 feet of altitude. Actually of course, temperatures vary considerably from the standard. If you wanted to know your altitude above the ground, you would take the reading of your altimeter (which, if set with sea-level as zero, would show you your altitude above sea-level) and you would then look on your chart to find out how far above or below sea level was the place over which you were flying. Imagine that you are flying from Point X to Point Y. Point X is at sea level. When you have climbed to 4000 feet, your altimeter (not considering errors) would read 4000 feet above sea level. However, you are going to Point Y, which is 1000 feet above sea level. When you reach Point Y, if your altimeter still registers 4000 feet, you would be 4000 feet up, minus the elevation of Point Y, which is 1000 feet. You would therefore be 3000 feet above the earth.

THE ALTIMETER MEASURES THE WEIGHT OF AIR ABOVE THE PLACE WHERE THE PRESSURE IS MEASURED, — NOT THE LEVEL OF THE EARTH'S SURFACE



According to standard conditions, pressure decreases with altitude.

In order to reduce the amount of error, there has been introduced, into the altimeter, in addition to the round dial, another reading where pressure is shown in inches of mercury, which can be set by means of a knob, to correspond with the local barometric pressure at any time. You must remember that the altimeter is adjustable so that any elevation or pressure may be used as zero. It will read ZERO FOR WHATEVER IT HAS BEEN SET TO, either sea level or the point of departure. For long, cross-country flights, it is always better to use sea level as zero. You may hear the term "pressure-altitude" used in this connection. This means the barometric pressure above sea level, expressed in feet of altitude when the scale is set to the standard pressure at sea level.

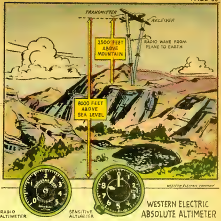
If you did not have errors to contend with the use of the altimeter would be very simple.

But the important fact to remember about the altimeter is that its READINGS REQUIRE CORRECTION. In reading its dial we must know to what errors it is subject and how to correct those errors.

One reason that an altimeter does not always tell you your exact, accurate altitude is because atmospheric pressure varies. The way in which this pressure changes with height above sea level is not the same everywhere at all times, nor is it even the same over the same place at different times. There is a daily variation or tide of pressure (stronger in southern latitudes). There is also a dynamic change in pressure, caused by the shifting of atmosphere and its pressure regions, which may amount to as much as 1.5 inches. An altimeter is a pressure instrument. Therefore a decrease in pressure will cause it to indicate increased altitude. Now if your plane is on the ground at sea level, with its altimeter set at zero, and the atmospheric pressure decreases, the pointer will move above zero and will indicate (falsely) that the plane is above the ground.

An altimeter reading of 500 feet would be correct if standard conditions prevailed, but where there is higher than standard pressure, the plane is really higher than the altimeter reading shows, and where there is lower than standard pressure the plane is really lower than shown by the altimeter. Actually the variation from the average is usually less than 0.2 inches, but this is enough to cause trouble. Since pressure decreases approximately 1 in per 1000 feet, conversely, for each 0.2 inches of decrease in pressure, the altitude registered is 186 feet higher—and this is some difference if you are trying to land in a fog!

As you fly over places of different sea level air pressure, you can adjust your altimeter setting accordingly. In flying from a place where prevailing barometric pressure is high, to one where it is lower, you should substract 100 feet from the altimeter indication for each 1/10 inch difference in pressure. If you fly from an area of low



WESTERN ELECTRIC ABSOLUTE ALTIMETER

pressure to one of higher pressure, you should add 100 feet for each 1/10 inch. If, for instance, you were flying in unfavorable weather, from Maryville (pressure 30.15 inches) to Belleville (pressure 29.85 inches) and you leave Maryville with your altimeter adjusted to pressure there, your altimeter when you reach Belleville will indicate that you are about 300 feet higher than you actually are. And are you in trouble! Remember—YOU MUST GO UP TO REACH LOWER PRESSURE!

Pressure at any elevation is somewhat influenced by temperature conditions. If the temperature is higher than standard conditions, the air is lighter per unit volume and the altimeter will not read 1000 feet until you are higher than 1000 feet. You will actually be higher than your altimeter tells you. If the temperature is lower, you will be lower than your altimeter tells you, and this may be exceedingly dangerous. A good general rule is that the correction is equal to 2% of the indicated altitude for each 10° F that the temperature differs from standard conditions. However, there are of course more specific methods.

Other errors in altimeter readings for which you must make allowances are caused by pressure turbulence over mountain peaks, and by possible mechanical defects which originate during flight in this delicate instrument. Also the altimeter always lags behind progress of the plane, whether ascending or descending. The greater the rate of change and the older the instrument, the greater the lag.

All these errors can be counteracted and allowed for by the experienced pilot.

Let us return for a moment to the three uses of the altimeter which we originally discussed. In obstacle clearance, all the variations must be considered. Charts of the territory below assist here, of course, but when over such terrain as dangerous mountains you must not only use the latest altimeter setting and traffic altitude given, but must give particular attention to temperature. It is a good idea to note the indicated altitude, then, without changing altitude, put the indicator at zero and correct for the temperature at the plane.

With regard to traffic altitude, if the altimeter is set according to the setting given by the nearest CAA stations, he can keep to the proper altitude for clearance. Also, before take-off, the pilot can get a copy of settings of important terminals, etc. on his route, which will help him during the first few hours of flight. During flight, he can adjust the setting according to the correct settings for various weather stations over which he passes.

For instrument landings, he should receive by radio the correct setting for the landing field at that particular time. When the altimeter is set, showing the local setting in the barometric window, the plane will land when the altimeter shows the surveyed elevation of the field. Or with the indices set at pressure altitude, the plane will land at zero.

There are, as we have stated, more specific and complicated corrections a pilot must make, after he has studied the subject intensively—and you will gather that the present instrument is not entirely satisfactory. However, improvements and new developments are continually being effected. Among other instruments under experimentation are the sonic altimeter which operates on the principle of reflected sound waves, and the terrain clearance indicator which uses reflected radio waves. Of these, the second is farthest advanced and is proving more practicable. It is actually a complete radio station, including transmitter and receiver, and measures altitude by sending a wave to the ground and determining the time required for the signal to make the trip from plane to ground and back. In the case of a 4000 foot ridge, for example, while the ordinary altimeter would show only that a plane was 7000 feet above sea level, the terrain clearance indicator would show that it was only 3000 feet above the ridge. The instrument has by no means been perfected. The signals are not very well reflected over rough terrain, and the instrument will not give clear indications of height above objects which have relatively small area, but constant research is improving it and it will probably eventually be one of the most vital aids to safe navigation over unfamiliar terrain.

At any rate, while the altimeter is one of the most important aircraft instruments, it is also one of the greatest pieces of "unfinished business" in the industry and much time and money are today being invested in its perfection. The problem of its improvement is a challenge to

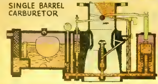
CARBURETION

IN order for a carburetor to do its job properly, it must have special devices to secure the proper ratios of fuel to air for special speeds—low, idling speed or maximum power or sudden acceleration, etc

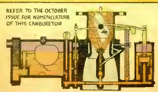
Primer The primer is a small pump which is used when starting the plane, to pump gasoline to the intake valves of each cylinder While the engine is cranked, the pilot operates this from the cockpit, giving the valves several quick shots so as to make sure that each cylinder has a rich starting mixture It is similar to the automobile choke

Idling System In order to make the proper mixture for an idling speed, an idling nozzle is provided at the edge of the throttle valve When the plane is idling, the throttle is so far closed that the air velocity past the main jet nozzle is almost zero and no fuel is drawn from the nozzle When this is the case, air is drawn out of the intake passage and high suction exists in this restricted area As the idling jet is just above the throttle and opens into this passage, the fuel which comes up through the idling tube to this jet is sprayed into the passage

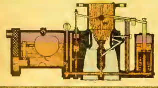
Accelerating System · Acceleration, or sudden increase of speed, requires a change in the mixture ratio We have seen that much of the fuel in the intake manifold is in liquid form. When the throttle is suddenly opened, the air and vaporized fuel in the manifold can flow quickly, but it takes more time for the liquid fuel to attain higher speed. The temporary addition of fuel for a quick pick-up is accomplished by the accelerating pump This is a cylindrical passage which has a connection to the float chamber As the throttle is opened or closed, a piston with a check valve connected to the throttle lever works the cylinder up and down During a gradual throttle opening, the check valve remains open and no fuel is pumped, but



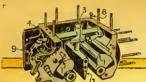
IDLING: Engine started, operating lazily Throttle almost closed No fuel drawn from main jet nozzle Fuel flows from float chamber past idling jet Small amount drawn into idling system Idle air bleed admits air to mix with fuel Mixture control —full rich Accelerating cylinder full of fuel, ready for acceleration.

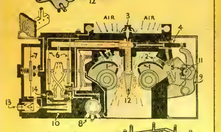


CRUISING: Engine operating at medium speed Passage to main discharge nozzle about half full of fuel Main air bleed furnishing air to mix with fuel Fuel flow regulated by main metering jet located under mixture control needle Mixture control needle up, in position for full rich mixture Economizer valve closed

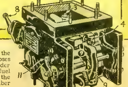


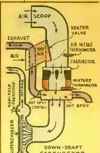
FULL THROTTLE: Engine operating at full power Economizer needle off seat, permitting full flow of fuel to main jet Fuel in accelerating pump cylinder forced into discharge nozzle to furnish additional fuel required Idling system empty of fuel so all air can go to vaporize large fuel supply





DIAPHRAGM-TYPE NONICING CARBURETOR (CRUISING POSITION)





DOWN-DRAFT CARBURETOR INSTALLATION

with a quick opening of the throttle the check valve closes and the contents of the cylinder are forced out so that extra fuel is delivered directly through the main jet from the float chamber into the air stream

Economizer Another feature of the carburetor is the economizer, which belies its name, because its purpose is actually to enrich the mixture at high speed (wide open throttle) so as to protect the engine against overheating At all speeds up to and including cruising, the economizer jet is kept in closed position by a spring Just over cruising speed a lever connected to the throttle lifts up a needle valve so as to allow more fuel to be admitted to the main jet from the float chamber, and at high speed, when the throttle is wide open, the economizer supplies the additional fuel necessary for full power

Altitude Control Still another device for controlling the mixture is the altitude control, which adjusts the mixture appropriately for various altitudes "The reason that a change is required for different altitudes is that changes in atmospheric pressure at various altitudes cause changes in the weight of air, while the weight of fuel never changes There are various types of mixture control but the one most commonly used is that in which the enrichment tendency is counteracted by partly closing a needle valve and thus reducing the amount of fuel permitted to flow through the main fuel passage. In small planes, this control is usually operated by hand, the pilot setting the mixture at FULL RICH at the take-off and then as the plane gains altitude, moving it toward LEAN

Heating the Carburetor. As carburetor icing is very disastrous, causing a great loss of power, most engines have a "hot spot" or means by which the pilot can cause either hot or cold air to be delivered to the carburetor

Although most aircraft carburetors operate on the principles we have been describing, their design varies considerably There are "up-draft" and "down-draft" carburetors the up-draft being the type which air enters from the bottom The down-draft carburetor is usually mounted at the top of the supercharger section above the intake manifold and insures a clean supply of air. Because aircraft carburetors are designed to be as light and compact as possible, several carburetors are often combined in one casting For engines up to about 300 hp a single barrel carburetor is usual, whereas those of higher hp. may have a carburetor of two or more barrels

Recent improvements in engine performance and operation over a wider range of speeds and at higher altitudes have created

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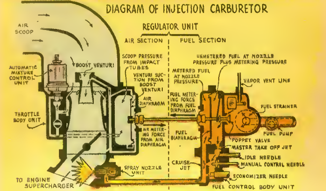
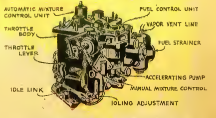
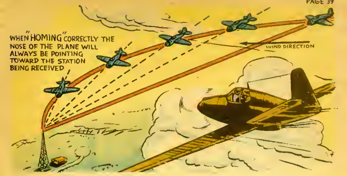




more critical carburetion problems. To cope with these new problems, new types of carburetors have replaced the basic float type. There is also the important question of carburetor icing. Ice which collects in the scoop is not affected by carburetor design, but ice which is caused by vaporization of the fuel can be avoided by proper design.

The diaphragm carburetor achieves this improvement and also keeps a full fuel chamber so that there is little slopping of the fuel to interfere with the metering job of the carburetor. Instead of the float chamber, this carburetor uses a diaphragm arrangement, in which the fuel chamber is the space between two diaphragms placed side by side. Fuel is pumped by the fuel pump into this chamber through a fuel valve. When the engine is running, the velocity of air passing the top main discharge nozzle hole creates suction which draws the fuel out of the top of the diaphragm chamber and into the metering channel. In the metering channel is a metering pin which is controlled by a lever and shaft connected with the throttle. As the throttle is opened and more air is taken into the engine, the fuel passage opening is increased by the movement of the metering pin. Other controls adjust the fuel-air mixture for various engine speeds, just as in the simple carburetor.

The Injector-type carburetor is entirely different from the other types with which we have dealt. It has a closed system from fuel-pump to discharge nozzle. The injector-type carburetor causes no ice formation from vaporization of the fuel. It has complete maneuverability, since the forces of gravity and inertia scarcely affect it. It gives automatic accurate metering at all engine speeds and loads, independent of changes in altitude, propeller pitch or throttle position, so that the correct fuel mixture is automatically supplied and its settings are uniform and simple. This carburetor has a spray nozzle which sends an exact amount of fuel spraying into the intake system by pressure, instead of having it drawn into that system by suction. Increased power, improved fuel economy, smoother operation and more dependable operation in every position of the plane result from the use of the injector-type carburetor.



THE RADIO COMPASS AND DIRECTION FINDER

BY ERNEST G. VETTER
Lieutenant-Commander, U. S. Naval Reserve
Author of "Let's Fly" and "Visibility Unlimited"

AN EXTREMELY interesting and highly practical instrument is the *radiocompass*. It represents one of the greatest advances in navigation systems and equipment since the early development of radio. Used as a receiver, it has three bands, the 200-400 KC or X band, the 550-1600 KC or A band, and the 2000-6000 KC or B band. With the addition of a loop antenna it makes possible another kind of radio navigation known a *homing*. If the loop antenna is of the rotatable type yet another branch of radio navigation called *direction-finding* is possible.

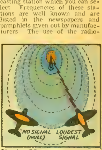
With the normal, fixed antenna, either the horizontal T-type or vertical mast, this set operates as an aural receiver, on all three bands. To use it as a range receiver, the switch in the center is set at Beacon Weather Regular, the knob on the left turned till the pointer is on the X or beam band, and then the range is selected on the frequency scale on the right side.

When the set is used as a radiocompass, which is its primary purpose, a loop antenna is required in addition to the regular aerial. The loop is placed so that it is secured directly across the plane parallel with the wings and is called a fixed loop because it is not movable except by moving the plane. The loop itself is electrostatically shielded in a streamlined housing.

The properties of a loop are such that no signals are obtained when the plane of the loop is at right angles to the direction of the transmitter to which the receiver is tuned. In this "null" position the airplane is headed directly toward or directly away from the transmitter. Maximum signals are obtained when the loop is in line with the broadcasting station and the airplane at right angles to it. Therefore, an airplane whose receiver is tuned to a certain transmitter when kept on a heading where the signals are "null" will head directly toward or "home" to that station. The same effect exists when heading away from the station. You know whether you are heading toward or away from a station by your relative location. On the AVR-8 the heading is usually indicated on a dial that works just like a turn indicator. After the set has been tuned to and headed toward a certain station, you merely keep the needle centered on the visual indicator and you will fly directly to the antenna system of the station.

With a radiocompass you are not limited to the ranges. If you are flying to a city that has a range station you can use the station to "home" on, but you can approach it from any direction and do not have to go out of your way to get on the beam.

If there is no range at the city to which you want to fly there is usually a commercial broadcasting station which you can select. Frequencies of these stations are well known and are listed in the newspapers and pamphlets given out by manufacturers. The use of the radio-



PROPERTIES OF A LOOP ANTENNA

compass is confined to the 200-400 KC radio beam weather band and the 550-1600 KC standard entertainment band. The high frequency bank of 2000-6000 KC is not available for radiocompass operation as the inherent characteristics of these frequencies make them unfit for this use.

An interesting feature of the radiocompass is that you can receive simultaneous visual and aural signals. When flying a course to or from a radio range beam station, you can fly by visual indicator and still receive the weather broadcast. When homing on a broadcast station with the visual indicator, you can at the same time enjoy the program of the station toward which you are headed.

When homing correctly, the nose of the airplane will always be pointing toward the station being received. If there is a side wind blowing, the airplane will be carried with the wing along a curving, steadily changing course towards the station. This change in heading automatically takes care of drift. It might appear that the airplane is going considerably out of its way flying in this manner. As far as time is concerned, it works out about the same as if a drift correction were made and the airplane "crabbed" on a more direct course.

Although we may be pretty certain that the radiocompass will bring us in all right, it is always advisable to plan the course regardless. We will not bother about the wind direction and velocity other than to notice its direction and estimate its strength and make a mental note of its effect on the course. If the wind is too strong the flight should not be made. If it is moderate the radiocompass will automatically correct for wind without any difficulty.

Of course, full consideration must be given to the terrain conditions and the weather before taking off. Next a radio station at the destination is selected. In case we wanted to fly from Winston-Salem, N. C. to Roanoke, Va., we could use either the Roanoke range station on 317 kilocycles or the commercial broadcasting station WDBJ on 930 kilocycles.

To fly the course by radiocompass the ship is first taken into the air, and after a safe altitude is reached, it is headed in the general direction of Roanoke, which is 15 degrees with slight variation for estimated wind effect. The headphones are adjusted over our ears and the set is turned on. If the range station is to be used, the band selector is set to the X position, or if the commercial station is desired, to the A position. After the tubes have warmed up the volume is adjusted and the station selected is tuned in on the tuning dial. The Operation Selector must be on the Beacon-Weather-Regular position, while the tubes warm.

When the desired signal is tuned in so that the station is being received, the volume is reduced to a minimum. The Operation Selector is then turned to the radiocompass position and the volume again adjusted so that the signal is at a comfortable level in the headphones. With adjustment of the sensitivity control on the indicator head the set is completely adjusted. Then, by heading so that the needle is centered, you will fly directly to the station in Roanoke to which you are tuned (all else being equal).

When this set is used as a radiocompass the antenna is a fixed loop. That is, the loop remains stationary and its plane is parallel with the wings of the airplane. A rotatable loop is one in which the whole loop rotates when a hand crank or a knob attached to it is turned. When the airplane has a rotatable loop, this same radiocompass may be used as a direction finder.

This term direction finder is not exactly accurate for the system actually determines positions instead of directions. Directions can be found from one or more positions but only after the positions are located. The principle of direction finding is to locate the position of the airplane at different times. From these successive positions the airplane's

direction of flight can be determined and its relation to a preplanned flight course can be seen. If the airplane is making good its course, no adjustments need be made. On the other hand if the various positions of the plane indicate that it has varied from the course the necessary corrections are made in the compass heading to bring the plane back on course.

To determine the plane's location or position the radio set is tuned to some radio station on the side of our course. The location of this station, of course, is shown on the chart. The loop is then rotated until the visual indicator is on zero. If the set does not have a visual indicator the loop is turned, after the station has been tuned in, until the signal is at its lowest volume or at the "null" position.

At this point the airplane is heading in one direction but the plane of the loop is turned so that it is perpendicular to the radio station selected, which is in another direction. Attached to the

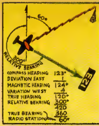
shank of the loop is a circular scale called the *azimuth scale*. A pointer on this scale will now indicate the number of degrees between the compass heading of the airplane and the radio station. This is called the *relative bearing*. It is not the bearing of the airplane to the radio station.

To obtain the true bearing of the airplane to the radio station we read the compass and then apply the deviation correction for that heading and the variation correction for that locality. Remember that in this case we are working from compass heading to true bearing, or really backwards,

so our rules given earlier are reversed. This will now give the true heading of the airplane. The true heading is now added to the relative bearing. If as frequently happens, the total is more than 360, then 360 must be subtracted. This might prove a bit confusing at first but study of the illustrations will make it clear. Now we have the true bearing of the airplane to the radio station and this can be plotted on the chart.

It is much easier, however, to plot the bearing of the radio station to the plane, since we know where the station is while the location of the plane is what we are trying to find. We merely use the reciprocal of the plane-to-station bearing to get the station-to-plane bearing. This is obtained simply by adding or subtracting 180 degrees. When the bearing of the station to the plane is obtained it is plotted from the point representing the station on the chart. This then represents a radio line of position and the airplane is somewhere along this line.

Another bearing is then taken on a different station in some other direction and a line of posi-



tion determined in the same manner. This second line of position is plotted on the same chart and the airplane is somewhere along this line also. If the airplane is somewhere along both of these lines, it is obvious that the exact point on both lines where the airplane is located is where they cross. This point then fixes the location of the airplane and is known as a *fix*. In practice bearings are usually taken on three radio stations for accuracy. A fix is marked on the chart with a small triangle and the line of position is marked with the time at which it is taken.

This taking of bearings and plotting of position looks and sounds complicated, but it can be done easily and quickly with practice. Once facility has been gained, all these operations can be performed much quicker than they can be explained.

A very convenient chart that saves considerable work in plotting bearings is the DF (Direction Finding Chart) of the Coast and Geodetic Survey. This is on a Lamber Conformal projection at a scale of 1 to 2,000,000 and six charts cover the entire United States.

It is obvious that, since radio bearings follow great circle courses, and a straight line on the Lamber is approximately a great circle, the scale error of this chart is negligible. Around each range station, and other important stations, are compass roses oriented to the magnetic meridian. There are two rows of figures, or scales, on the compass rose. The inner figures form the conventional magnetic scale. The outer figures start at zero at the south and show reciprocal magnetic bearings of the station concerned.

In using the DF chart it is not necessary to do much figuring. As the compass roses on the chart are magnetic we can use the magnetic heading instead of the true heading to get the magnetic bearing of the station. Nor is it necessary to calculate reciprocals as they are given on the compass rose of each station.

Let us take a practical example and see how the chart can be used. We are flying from Dayton, Ohio, to Evansville, Indiana and would like to locate our position. First, we read the compass and find we are heading 244 degrees. As the deviation on this heading is 2 degrees west, our magnetic heading becomes 242 degrees. Tuning our set to 266 KC, we find with the pointer on zero that the Indianapolis range shows a relative bearing of 86 degrees. When this is added to the magnetic heading of 242 we obtain 328 degrees, the magnetic bearing of our plane to the station. We draw a line from the Indianapolis range station through the outer 328, giving a radio line of position. Next, tuning the set to the Cincinnati range 335 KC, we see that the relative bearing is 210 degrees. When this is added to the magnetic heading of 242 the sum is 452. Subtracting 360 the magnetic bearing to the Cincinnati station becomes 92 degrees. The next step is to draw a line from the Cincinnati range through the outer 92 point, and the second line of position is completed. The point at which these lines cross represents our position, but for confirmation we will take a third bearing.

Tuning to the Louisville range on 284 KC our relative bearing is 286 which added to the magnetic heading of 242 becomes 528. Deducting 360 leaves 168 and we

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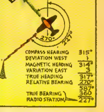
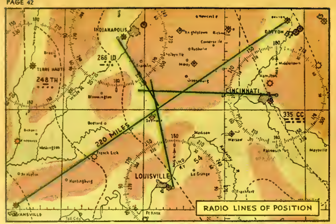




RADIO LINES OF POSITION

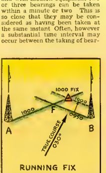
draw our third line of position from Louisville through the outer scale at 168 If our calculations have been very precise this line will pass through the intersection of the first two lines More likely it will be somewhat off and the intersections will form a small triangle Our position may then be taken as the center of the triangle, which is just south of the little settlement of Columbus

This indicates we have traveled off the course by about 6 degrees which amounts to about ten miles in this case By modifying our compass heading and taking later bearings it is possible to get back on course and to remain there.

If the set does not have a visual indicator, the null position can be used to take bearings. Bearings can also be taken with a fixed loop, but the whole airplane must be turned in order to locate the null position.

Because the radio bearings follow great circle lines a correction must be made when a Mercator chart is used on long courses This correction may be ignored if the radio station is known to be less than 50 miles away. There are other details that come to light in further study and practice, that when observed will make for more precise results

In the earlier explanation of a fix it was assumed that the cross bearings were taken at the same time Under favorable conditions and with modern equipment two or three bearings can be taken within a minute or two This is so close that they may be considered as having been taken at the same instant Often, however a substantial time interval may occur between the taking of bearings The position of the airplane is then determined by what is called a *running fix*, which involves moving the lines of position to the same moment in time.



RUNNING FIX

For instance, A and B are radio stations and AF and BF are radio lines of position from them intersecting at F Bearing BF was taken at 10 minutes before 10 o'clock and bearing AF was taken at 10 o'clock. As the plane was making good a course of 030 degrees at a ground speed of 85 miles per hour, it is obvious that it could not be at F at 10 o'clock. But, knowing that the airplane was somewhere along AF at 10 o'clock, and somewhere on BF at 10 minutes before, we merely move BF along the true course the distance traveled in 10 minutes, or 14 miles Then at 10 o'clock the airplane would be at the point marked 1000 fix.

Direction finding is of extreme value in flying over water or unfamiliar territory where landmarks are either unavailable or unsatisfactory. Position finding is of great help in dead reckoning and an extremely valuable aid to instrument flight. But it is of more practical value where personnel to do the work is available.

"PLAYING to a full house, the entire United States invasion fleet in the Gulf of Salerno, ten tight-lipped American youths flying P-38 *Lightnings*, demonstrated today their supremacy over the German Air Force and their plane's superiority over Germany's best fighter, the Messerschmitt 109.

"They slugged it out with more than twice their number, choosing to fight when there was ample time to flee Out of the resulting maelstrom of planes, which kept ground troops goggle-eyed and seamen breathless for twelve minutes, five fell to earth, all German Not a single P-38 was lost"

So runs an article on the second page of the New York Times, one day in mid-September this year of 1943. Could there be a more eloquent testimonial to the champion qualities of the Lockheed *Lightning*?

Known officially to the Army as the P-38 Interceptor Pursuit, this plane, which has a score of speed and distance records to its credit, looks for all the world like two silver bullets mounted on the blade of a gleaming sword.

Sleek, shining, and as dangerous as it is beautiful, the *Lightning* is the last word in streamlining, embodying all the modern principles of aerodynamics. Its unconventional design is chiefly visible in the twin booms which take the place of the customary fuselage and provide added ruggedness and safety The pilot-gunner in this twin-engined, single-place plane, rides in a bullet-like nacelle which is an integral part of the wing. All the cannon and machine guns are carried in the nose of this nacelle, directly in front of the pilot-gunner and the controls of this concentrated firepower are at his fingertips.

The *Lightning* has been described as the fastest airplane in the world and engineers state that no plane could withstand the full firepower of this ferocious fighter

Two slender nacelles, on either side of the pilot, each carries a

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ALL RESEARCH AND PROJECT ENGINEERS, these five men, working under a conference system, designed the P-38 L to R., they are Dick Pulver, C L Johnson, H. L. Hibbard, Joe J. Johnson and J Gerschler.

PLANES ASSEMBLED along continuous conveyor lines, go up one line, down second, up third, out.

READY FOR ACTION, this P-38 sets out to justify the time and effort devoted to her production.

twelve-cylinder, liquid-cooled Allison engine. These nacelles extend like torpedoes back to the twin-tails of the plane, supplanting the conventional fuselage.

The *Lightning* has a gross weight of about 13,000 pounds, wing span of 52 feet, and is 38 feet long, but stands only nine feet high from the ground to its propeller tips. The two three-bladed controllable pitch propellers rotate in opposite directions.

Of its speed, military regulations permit only the terse description "in excess of 400 miles per hour" concerning its remarkable climbing speed, "an exceedingly high rate of climb." Of course, both these factors are vital to an interceptor-pursuit type of plane, which must get off the ground quickly at the first sign of approaching enemy bombers, climb swiftly to altitudes of 35,000 feet and greater, and dive down through the fighters that escort the bombing squadron, chasing fighters and bombers alike out of the sky.

The plane virtually "stands on its tail" in its skyward search for trouble. Due to its weight, plus power and streamlining, it will zoom thousands of feet higher than any other fighter before it "falls off"—and zooming is vital in combat.

Not only will the P-38 climb faster than any other ship—faster than the Zero by nearly half again, but once in this substratosphere, it will maneuver firmly at altitudes where other ships are "staggering" in the thin air. Turbo superchargers, which maintain a constant power output in the rarefied substratosphere make it possible for the ship to maintain its phenomenal sea level performance at high altitudes.

Only recently were Lockheed engineers themselves able to compute how fast their P-39 was diving. Until then, they only knew that airspeed indicators fall far below that speed and record a "shock wave" of air which has no bearing on true speed.

The longest vertical dive in history—nearly five miles—made at 780 miles an hour in a *Lightning* by Lieutenant Colonel Cass Hough of Plymouth, Mich., is described by the Chief Engineer of Lockheed in these words: "He told me he went straight down—vertical—in a full power dive, everything wide open, and that he hollered like a banshee all the way down from 43,000 to

BOMBER AS WELL AS FIGHTER, this versatile ship can lift thousands of pounds with little loss of speed. Bombs 100 lbs and up are carried under the wings

STREAMLINED DROP TANKS for additional gasoline are produced by Lockheed one every 4½ minutes. Plane has tanks, bombs, or both, on under-wing brackets

18,000 feet. Then he leveled off in a wide arc and was in level flight again at about 8,000 feet."

The P-38 excels in fire power, too. Its four big machine guns and cannon are concentrated in the nose where they can fire all-out without being slowed down to synchronize with the propeller, and they are aimed with rifle accuracy by the pilot. Thus, the P-38 pumps a deadly column of lead, effective at any range, and able to chop the wing off a Messerschmitt or saw a Zero in two.

There is no "cone of fire" which is concentrated at one "ideal" range and widely scattered at all others. The *Lightning* is a solid slugger at any distance (as proved when a flight of P-38s in the Aleutians shot down five Zeros and one four-engined flying boat in a single dive.) As far as the tracers reach, the fire is withering and it remains a stream, not a spray.

The value of twin engines has been proved in action by these Lockheeds, which on one engine alone can fly with ease. This tremendous safety margin has saved many pilots, and will save more. In the Aleutians a *Lightning* pilot flew 150 miles back to his base with one engine shot away.

Another hidden virtue in the twin engines, rotating in opposite directions, is equal maneuverability, to left or right, with no torque effect to be overcome. Many Nazi ships have been shot down since it was learned that they could come out of a dive *only* toward the right, because of torque reaction at high speed. The *Lightning* has no torque reaction and will turn readily in either direction at any speed.

So we see that its shattering fire power, zooming climb and lightning speed make this plane an ideal interceptor pursuit ship.

But the *Lightning* is also rated as the most versatile of fighters. This is partly because it is the greatest weight-carrier of all, due to the 2300 horsepower of its two Allison liquid-cooled engines, to its highly efficient wing, and to its amazingly clean aerodynamic lines—so clean that 60 percent of the ship's drag is in the tricycle landing gear, until the gear folds into the slender wing immediately after the take-off.

Part of its weight is armor for safeguarding the pilot and vital parts, some is self-sealing fuel tanks, and much of it is armament and equipment, but the bulk of it is sturdy airframe construction with maximum ease of replacement. A crumpled wing on a Zero calls for a new Zero; on a P-38, it calls for a new wing. Much credit for this ruggedness goes to the P-38's ribless wing with double-skinned and double-stressed design. Flying stresses are shared by the skin and spar of the wing.

The basic *Lightning* with no drop-tanks, has a wider range than most fighters and this range applies when the ship is carrying its two-ton extra load of armament. The extra load may be bombs, tanks for laying smoke screens, equipment for delivery to ground forces, or additional gasoline tankage for ferrying or for extending the *Lightning's* range. Bombs or droppable tanks all hang from the same special brackets under the ship's sturdy wing, and may be carried in any combination such as one bomb and one large tank.

Droppable tanks of 150-gallon capacity are used for distant fighting or escort missions and give the P-38 an effective combat range of 750 miles—just right for convoying bombers over Berlin with ample reserves for combat. This range in the P-38 has made possible an entirely new bombardment technique, extending the essential "fighter-cover" for daylight bombing to distances otherwise impossible.

Bombs are released with the same deadly accuracy as cannon shells and with the same sights, for the speed of the *Lightning*

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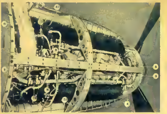
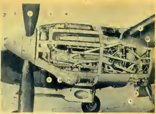
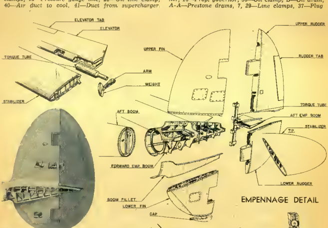


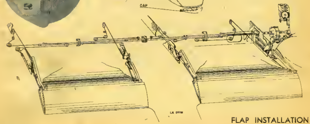
TOP VIEW OF ENGINE. 1, 8, 20—Prestone line clamps, 13—Pressure gauge line, 22—Oil line clamp, 40—Air duct to cool, 41—Duct from supercharger.



SIDE VIEW OF ENGINE. 1—Propeller unit, 2—Spinner, 18—Prop. governor, 30—Oil clamp, B—Oil drain, A-A—Prestone drains, 7, 29—Line clamps, 37—Plug



EMPENNAGE DETAIL



FLAP INSTALLATION

hurls the bomb straight into its target from low altitudes—then whips the ship away from the blast. The P-38 was not originally designed for bombing, but its willingness to lift thousands of pounds with slight loss of speed has pressed it into service on this unexpected assignment.

Without its extra loads, the P-38 will climb to more than 30,000 feet and fly "well over 400 miles per hour," yet it maneuvers effectively against fighters with half its own unusually heavy wing-loading of 48 pounds per square foot.

This incredible range in performance is achieved by a quick-acting "maneuvering flap" which greatly increases the lift of the wing with almost no effect upon its drag. This flap can be lowered in three seconds and raised in four. Thus the *Lightning* can take off on an interception or other mission; reach its target with unsurpassed speed—and in three seconds become a highly acrobatic dogfighter, dive bomber, ground strafer, or precision bomber under conditions of bad visibility or hazardous terrain. Then, the maneuvering flap may be raised again, restoring all the P-38's speed for the trip home.

The same flap shortens the take-off run, especially in mud or snow, until the ship can operate from small fields formerly closed to fast ships.

And this unique feature puts the *Lightning* in a class by itself as a photographic ship as well as a fighter, able to venture out with no defenses save speed and altitude, and bring home close-up shots of enemy strength or bombardment damage.

This is the real P-38—the ship which was kept under wraps until the time was ripe. The American Air Forces battle-tested it only on isolated fronts; proved it, developed new tactics to match its performance, and then hurled it into major warfare as a smashing blow.

The "Lightning" is in mass production with increasing volume for the United States Army Air Corps at the Lockheed Aircraft Corporation in Burbank, California. Its twin booms, its two Allison engines, its two superchargers, and its intricate cooling system had caused many leading production experts to declare that it could never be built on a mechanized assembly line.

But just eight days after Lockheed engineers went to work changing over to a master assem-

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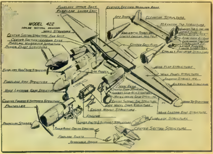
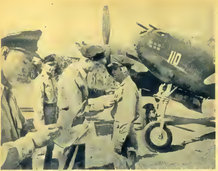
LIGHTNINGS LINED UP at Lockheed plant in Burbank, Cal. while workmen give them a once-over. Soon these planes will be ready for delivery to worldwide fronts—to strike the enemy as only lightning can





SEVEN JAP PLANES MET DEATH is the story told by insignia of this P-38. Resting on her laurels, she watches Captain T G Lamphier, Jr receive D.S.C and Silver Star from Brig Gen Strother at Pacific base

bly scheme, the sorely needed planes were rolling down a continuously moving conveyorized line (similar to the automotive industry) And this improved assembly line resulted in a 40% reduction in man hours per plane.

Not so long ago Lightning P-38s made a mass ocean-crossing in the world's first trans-Atlantic ferry flight by fighter aircraft, thus going to war under their own power and releasing shipping space for other cargo Dozens of them continued to the African front after a training period in England, for a Burbank-to-Africa journey of more than 8,000 miles It is conceded that no fighter plane except the P-38 with its great droppable gasoline tanks, could have flown such distances across water and over enemy territory Since this mass flight across the North Atlantic, P-38s have been ferried greater distances across the South Atlantic and the Pacific

The P-38s were teamed with B-17 *Flying Fortresses* for the transatlantic journey, the Fortress crews taking care of navigation and each Fortress guiding several of the fighters The fighters were especially equipped for the Atlantic voyage, carrying additional long-range oxygen equipment as well as the droppable gas tanks of a type made of fender steel (which Lockheed turns out at a rate of one every four and a half minutes). Arctic packs with rubber boats were carried on water hops, replaced by "jungle kits" for stretches across dry land, both including concentrated rations.

The combat record of the P-38 over Europe is difficult to evaluate properly. One reason for this is German fighters' repeated refusal to come up and fight, so that in many cases the bombing mission is carried out with little or no opposition Another is, of course, the censorship

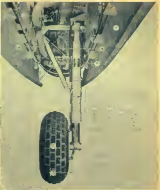
But despite the veil of censorship, innumerable are the tales of the daring exploits and almost fabulous achievements of the deadly P-38 Over European, African and Southwest Pacific fronts, the Flying Fortress with its protective cover of Lightnings has struck again and again at the enemy's strongholds at longer range than would be possible for any other combination of fighter and bomber—and harder than most

And the *Lightning*, designed as a single-purpose airplane—to intercept and destroy bombers at their maximum elevation—has shouldered one burden after another, until it became the world's finest and most versatile all-purpose plane, serving as fighter, bomber, interceptor, camera ship and special duty champion

TWO UNITED NATIONS CHAMPIONS meet, as Lightning and British Spitfire alight at an Allied air base.

FIREPOWER is deadly in this champion plane. Four big machine guns and cannon are concentrated in the nose, where they can fire all-out. The Lightning carries a heavy load of guns and ammunition, and is a solid slugger, effective at any range. In most comparative firing tests, the P-38 is reserved to fire last, because when it has emptied its guns, the standard target is blown to bits. The P-38 doesn't "damage" its target, it actually destroys it.

RADIO INSTALLATIONS of bewildering complexity are located behind the pilot's seat in the Lightning. By this means, the fast-maneuvering ship is kept in constant communication with squadron leaders and headquarters



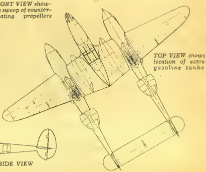
MAIN LANDING GEAR
HYDRAULIC DIAGRAM

CARRYING TWO DROP TANKS FOR GASOLINE, the Lightning can almost double its normal range

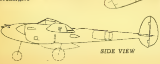
SPECIFICATIONS

MANUFACTURER: Lockheed Aircraft Corporation
COMPANY MODEL OR DESIGNATION: 222, 322, 422
ARMY DESIGNATION: P-38
NAME OF PLANE: Lightning
TYPE: Military (Fighter)
CREW: 1
POWER PLANT:
No. of Engines: 2
Make of Engines: Allison V-1710 F2 liquid cooled in-line
Rated horsepower: 2300 (1150 per engine) X
Propeller (make): Curtiss Constant Speed, Full Feathering
Diameter: 11 ft., 6 in. (3 blades)
PERFORMANCE: High speed, 400 mph class 410 mph
WEIGHT: Gross weight, 13,500 lbs.
DIMENSIONS: Span 52′, Length Overall 37′ 9 11/16″, Height Overall 9′ 10¼″
LANDING GEAR: Tricycle type, retractable
ARMAMENT: Four machine guns, one cannon
SUPERCHARGERS: Two turbo superchargers

FRONT VIEW showing sweep of counter-rotating propellers



TOP VIEW shows location of extra gasoline tanks



SIDE VIEW

MARAUDERS

HEROIC CREW OF MARTIN B-26 "Hell Cat." Captain Potter (back, 2nd left) was also navigator on General James H. Doolittle's Tokyo raid.

MARTIN B-26 Marauders are fighting a powerful battle on all war fronts, scoring ferocious jabs at enemy strongholds and ridding the skies of hostile planes which attempt to swerve them from their destructive missions.

The three Martin medium bombers whose crews are shown in these pictures have just returned from North Africa, where they participated in a combined total of 130 missions, downed 23 Axis planes, sank six Axis ships and three submarines. The boys are pretty cheerful about the whole affair, but it's no state secret that every one of them holds the Air Medal and some have higher decorations.

Names for the planes vary according to the tastes of the respective crews—which means that they differ widely but are always original, and, to say the least, piquant. These three are JABBO, the SKY KING, LADY HALITOSIS, and the HELL CAT (not to be confused with the new Navy fighter, the Grumman Hellcat).

LADY HALITOSIS doesn't hold much charm for the Axis. She has to her credit 43 missions in Africa, six enemy planes, three subs and one ship.

FLY LEAVES

ONE of the finest series of books for students of preflight aeronautics is the new McGraw Hill Flight Preparation Training Series, published under the supervision of the Training Division, Bureau of Aeronautics, U. S. Navy. These books are simple and clearly written texts, generously illustrated with pictures and diagrams of all types. The subject matter of each book is divided into its natural study units, each forming a chapter, and then it is further subdivided so that the material is easily absorbed and remembered. All the books are published by the McGraw Hill Book Company, Inc., 330 West 42nd Street, New York.

MATHEMATICS FOR PILOTS is the first of this series and covers the fundamentals of mathematics which a pilot must know in order to solve navigation problems quickly and correctly and in order to understand the basic principles of flight. A wrong answer to a mathematics problem may cause a crack-up and great loss in human lives. So this mathematics book provides a great many drill exercises. It makes the student drill until he knows the essentials so thoroughly that they are automatic and in most cases he can do them in his head. 75¢.

PHYSICS MANUAL FOR PILOTS—

This book contains only the rudimentary principles of physics which every pilot must know so that he may readily understand the theory of flight and engine operation. The treatment is not conventional, as material not essential for prospective pilots has been eliminated and the topics covered have been taken up in order of mathematical difficulty, (i.e. those topics requiring only a minimum knowledge of math have been dealt with first) so that the course may run parallel with a simultaneous course in basic mathematics. 90¢.

PRINCIPLES OF FLYING—

This book acquaints the student with the fundamental principles of flight and the essentials of airplane construction. Mathematical formulas are included only when they are inevitable, in order to show why certain principles are true, and those included must not necessarily be memorized. $1.50.

OPERATION OF AIRCRAFT ENGINES is an elementary and easily understood introduction to aviation engines, dealing chiefly with the simpler engines of low horsepower, which the student will meet early in his flying career. Since the knowledge and understanding of his engine is of the greatest importance to any pilot, this simply written basic book is a real contribution. 90¢.

AEROLOGY FOR PILOTS describes the influence of the weather on flying, showing how atmospheric conditions affect flying. This is a practical, rather than a theoretical book; it stresses the understanding of weather reports and forecasts, and shows how to interpret one's own observations so as to avoid dangerous flying conditions, in so far as possible. $1.25.

AIR NAVIGATION. The Flight Preparation Training Series includes seven manuals on the various phases of Air Navigation. Practical application of theories through the use of copious exercises characterizes all these books. The subjects covered are "Introduction to Earth, Introduction to Navigation, Dead Reckoning and Lines of Position, Navigation Instruments, Relative Movement, Contact Flying, Nautical Astronomy, and Celestial Navigation." $1.00 each.

EFFECTS OF FLIGHT. This volume explains to the pre-flight student the various physical reactions and sensations which he will experience when he begins actual flight training. It familiarizes him with the causes and manifestations of these reactions, so that he will be better to cope with them. Such psychological preparation is exceedingly important and prevents many failures which would otherwise occur during early flight training. Information on first aid is also included. 60¢.

MANUAL FOR AVIATION CADETS tries to develop in students the proper mental attitude toward flying, so that they will have some conception of what

they are up against and what is expected of them when they get into a plane and go up The book uses the direct approach, being almost a one-sided conversation. It is as though your instructor were speaking to you and offering you plain, common-sense facts about learning to fly. Maneuvers are described just as he would direct them through the speaking device of a plane. Chief emphasis is on the ways of thought a student should cultivate and this is of course worth-while for young cadets and would-be flyers. McGraw Hill Whittlesey House, $2 50

HOW OUR ARMY GREW WINGS—
Charles de Forest Chandler, Late Colonel, U. S. Army, and Frank P. Lahm, Brigadier General, U. S. Army, Ret
This is the history of early military aviation—the story of airmen and aircraft before 1914. It is the story of the tragedies and triumphs of the "firsts" in Army aviation, the adventures of the pioneering pilots of those early days, and the struggles of the inventors and constructors of the planes and other craft. We of today, reading this story, should find ourselves imbued with deep and abiding pride in our predecessors and in the progress which has grown from their strivings and achievements. Ronald Press, 15 E 26th Street, $3.75.

HORIZONS UNLIMITED—
S. Paul Johnston
HORIZONS UNLIMITED is the story of a man's gradual mastery of the airways. Centuries of effort and struggle were necessary before da Vinci's embryonic ideas became the giant airliner of today, and the record of this evolution includes some of the greatest milestones of human progress. The story is of men and their inventions, of history in the making—of the conquest of the air by the wings of man Mr. Johnston has divided his material according to the various classifications of aircraft and has developed each as a separate unit. To read his book is to extend our own mental horizon, to gain perspective upon present developments and to learn that vistas of the future of aviation are indeed HORIZONS UNLIMITED Duell, Sloan & Pearce, Inc $3.75.

PSYCHOLOGY FOR THE FIGHTING MAN prepared by a sub-committee of the National Research Council of which Edwin G. Boring was the chairman, is one of a series of military books co-published by Penguin Books and the Infantry Journal. It is written in a popular style and planned to meet the needs of all classes of fighting men. The chapters may be read in any order at all without losing their effect The book explains the proper uses of the sense organs in war. It analyzes the importance of training and the factors for efficiency in the army It tells about morale and emotions and fear and anger, about rumor and propaganda, about all the various personal and psychological problems faced by soldiers and sailors in this global conflict It helps servicemen deal with many problems they might otherwise find disturbing. Penguin Books, Inc., 245 Fifth Ave., New York City. 25¢.

CONTINUED ON NEXT PAGE

" HE FROZE AT THE STICK ! "

BACK NUMBERS

Any previous issue of Flying Cadet may be obtained from the publishers, postpaid, at twenty five cents ($.25) per copy. When ordering back numbers, please refer to the following complete list.

Vol. 1. No. 1. January, 1943
Vol. 1. No. 2. March, 1943
Vol. 1. No. 3. April, 1943
Vol. 1. No. 4. June, 1943
Vol. 1. No. 5. August, 1943
Vol. 1. No. 6. September, 1943
Vol. 1. No. 7. October, 1943

Due to limitations on the use of paper, imposed by the War Production Board, there have been no issues of Flying Cadet this year dated February, May or July. The magazine will be published monthly, without interruption, in the future.

Subscriptions are accepted to start only with the first number following the issue that is current at the time the subscription is received. Mail subscriptions and orders for back numbers to Flying Cadet, 420 Lexington Ave., New York 17, N. Y.

FLY LEAVES

THE AVIATION MECHANIC—
Carl Norcross, Major, U.S. AAF, and James D. Quinn, Jr., Lieutenant, USNR.

This is a complete and accurate textbook dealing with every subject the aviation mechanic must know. There are three main parts—introductory material about the airplane, its parts and nomenclature, and how it flies, the construction of airplanes and the maintenance and repair of airplanes. Included in the second section is a step-by-step description of the building of a light-all-metal airplane. All the manufacturing processes are discussed. It is a good idea for pilots to improve their general aviation background by reading this book . . . especially the section on maintenance and repair. McGraw Hill Book Co. $3.00.

THE AIRPLANE AND ITS ENGINE—
C. H. Chatfield, C. Fayette Taylor, Shatswell Ober

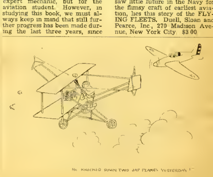
The need for a fourth (1940) edition of this book makes it an evident fact that it has its own place in aeronautical literature. THE AIRPLANE AND ITS ENGINE gives a broad discussion of the airplane and its power plant and a sound analysis of basic principles. It is keyed not for the designing engineer or the expert mechanic, but for the aviation student. However, in studying this book, we must always keep in mind that still further progress has been made during the last three years, since this edition appeared. McGraw Hill Book Company, Inc., 330 West 42nd St. $3.00

THE SKY'S THE LIMIT—
Charles Gilbert Hall and Rudolph A. Merkle

This book is well worth the reading for anyone who wishes to find his place in commercial aviation. It gives a comprehensive description of all the multiplicity of jobs which have become available in the magically expanding aviation industry and the preparation and training necessary. The background, education and physical requirements for each position and the kind of work performed in each case are also outlined. This is a practical and readable book. Funk & Wagnalls Co., 354 Fourth Ave., New York City. $2.00.

FLYING FLEETS—
S. Paul Johnston

For those who like a vivid picture book containing interesting explanatory text, here is the history of three decades of U. S. Naval Aviation, told graphically and in unique manner, chiefly by means of photographs. Between the today which considers aviation an indispensable part of the Navy, adding immeasurably to its striking power, and the yesterday when reactionary officers saw little future in the Navy for the flimsy craft of earliest aviation, lies this story of the FLYING FLEETS. Duell, Sloan and Pearce, Inc., 270 Madison Avenue, New York City. $3.00



HE KNOCKED DOWN TWO JAP PLANES YESTERDAY!

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933 Of Flying Cadet, published monthly at Chicago, Ill. for Oct. 1, 1943

County of New York } ss
State of New York }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Archer A. St. John who, having been duly sworn according to law, deposes and says that he is the Editor and Business Manager of the Flying Cadet and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Flying Cadet Publishing Co., 420 Lexington Avenue, N. Y. C. Editor, Archer A. St. John, 420 Lexington Avenue, N. Y. C. Managing Editor, T. J. Underwood, 420 Lexington Avenue, N. Y. C.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) Archer A. St. John, 420 Lexington Avenue, N. Y. 17, N. Y.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is (This information is required from daily publications only.)

Signed, ARCHER A. ST. JOHN

Sworn to and subscribed before me this 4th day of October 1943

(SEAL) WALTER PETRUZZI,
(My commission expires March 30, 1944)

A. A. F. INVADES BROADWAY!

MOSS HART, author and director of "Winged Victory" (civilian, center) in conference with his backstage staff to insure smooth performance

THE Army Air Forces are taking over at New York's 44th Street Theater for "Winged Victory," the show written by Moss Hart at the direct request of General Henry H. Arnold.

The play is a straight dramatic offering in twenty scenes. Proceeds will go to the Air Corps Branch of Army Emergency Relief.

In collecting background material for the show, Mr. Hart traveled 15,000 miles by bomber, in a two-month tour of national air bases.

In the huge task of recruiting professional talent, Lieutenants Irving Lazar and Benjamin Landis, general production managers, traveled 40,000 miles, holding preliminary auditions at all major air bases. All Air Forces Special Service Officers combed their posts for men who could qualify for the show and who, at the same time, could be temporarily released from their duties.

Among the soldiers who have been assigned prominent roles are Edmund O'Brien, Claude Stroud, George Reeves, Alan Baxter, Peter Lind Hayes, Ray McDonald and the Slate brothers.

EIGHT MEMBERS OF THE CAST during a rehearsal of the Army Air Forces dramatic production. Over five hundred soldiers were auditioned

FLYING CADET BY-LINES

LIEUTENANT ALEXANDER JOSEPH, Instructor of Aeronautics, U.S. Army Air Corps, and one of the country's outstanding aviation writers, has joined the staff of FLYING CADET. His articles on Aerodynamics and Aircraft Engines will appear in future issues.

Lieutenant Joseph has had long experience in interpreting various phases of aeronautics to pre-flight and aviation students. He has been a ground instructor and a consultant for aviation education for the Civil Aeronautics Association. He was Instructor of Aeronautics at the Bronx High School of Science, at Fordham University, and at Teacher's College, Columbia University. He is the author of FUNDAMENTALS OF MACHINES and of SCIENCE FOR NEW YORKERS, and co-author of the SMITHSONIAN SCIENTIFIC SERIES. He is best known, however, for his *Airplane Structures* and *Aerodynamics* sections of the SCIENCE OF PRE-

FLIGHT AERONAUTICS, a book compiled by the Aviation Education Research Group of Teachers College, Columbia University, with the cooperation of the Civil Aeronautics Administration and under the sponsorship of the Institute of Aeronautical Sciences

His interest in aviation began when as a boy, living in France, he spent much of his time at Le Bourget Field just outside of Paris

QUIZ ANSWERS

Questions on Page 6

1. A flyer calls for help on his radio phone by saying "Mayday." This was originally a French "S.O.S.," an adaptation of "M'aidez!" (help me!); 2. A Great Circle route is simply any direct route on the globe, as shown by stretching a string between any two points; 3. About 1400 miles; 4. As the density of air amounts to 14.7 pounds per square inch at sea level, but goes down to half of this weight at 18,000 feet, half of all air will lie below this height; 5. These are airports: (1, Army, Navy or Marine Corps Field, 2, Commercial or Municipal Airport, 3, Seaplane Base; 4, Department of Commerce Intermediate Port; 5, Marked Auxiliary Landing Field); 6. Hawaii is nearest the Aleutians; 7. Maine is nearer to Africa's coast than either Florida or Panama; 8 Centrifugal Force from seat to head causes "red out" or red vision. This is from the blood rushing to the head; 9. Anoxia, lack of oxygen, begins to affect the flyer (with oxygen equipment) at over 37,500 feet

MEDICAL MISSION!

An urgent request for medical supplies is received from an isolated outpost. Dressings, drugs, plasma . . . all needed in a hurry. Terrain too tough for land vehicles.

But, the vital, life-giving supplies go through to their destination quickly and surely in the Piper L-4 "Grasshopper " Parachutes carry the precious cargo to our hard-fighting boys. Wounds are healed, lives are saved . . . thanks to this wartime version of the famous Piper Cub.

It also directs artillery fire and troop movements, acts as a scout, transports officer personnel and delivers messages. The Piper L-4 is ideal for these duties because of its remarkable maneuverability and because it can land quickly almost anywhere and be hidden easily. These wartime uses and developments in design promise you a finer, safer, more economical peacetime Piper Cub.

FREE BOOKLET ON HOW TO FLY. Send today for your copy of "You, Too, Can Fly!" If you also want the full-color Piper catalog, enclose 10c in stamps or coin for postage-handling. Piper Aircraft Corporation, Dept. FC113, Lock Haven, Penna.

16mm. SOUND FILM—"The Construction of a Light Airplane " For distribution points write, Supervisor, Audio-Visual Aids, Extension Services, Penna. State College, State College, Penna.

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